THE JOURNAL and CERAMIC ABSTRACTS

AMERICAN CERAMIC SOCIETY

MAY • 1941

MONTHLY PUBLICATION DEVOTED TO THE ARTS AND SCIENCES RELATED TO THE SILICATE INDUSTRIES

TABLE OF CONTENTS

Vol. 24 May, 1941 No. 5

THE JOURNAL

Effect of Zircopax Additions on Abrasion Resistance and Various Properties of Several Glazes 145–47
By C. H. Commons, Jr.

Compositions and Properties of Some High-Titania Ceramics 148–55
By Louis Navias

Study of Eutectic Fluxes in Semivitreous and Vitreous Whiteware Bodies 155–59
By C. R. Austin and S. J. Brooks

Tantalum Glass: K_2O–Ta_2O_5–SiO_2 Series 160–67
By K.-H. Sun and Alexander Silverman

Use of Liquid Surfaces as Standards of Specular Gloss 167–70
By D. G. Moore and R. S. Hunter

Study of the Effect of Soluble Salts Present in Enamel Mill Liquors 171–78
By T. L. Hurst and A. I. Andrews

CERAMIC ABSTRACTS

20—5

Abrasives 109
Art and Archeology 110
Cements 112
Enamel 112
Glass 113
Structural Clay Products 117
Refractories 117
Terra Cotta 120
Whiteware 120
Equipment and Apparatus 122
Kilns, Furnaces, Fuels, and Combustion 124
Geology 125
Chemistry and Physics 127
General 130

Publication Office: 20th & Northampton Sts., Easton, Pa.
Editorial Office: 2525 N. High St., Columbus, Ohio
Entered as second-class matter at the post office at Easton, Pa., under the act of March 3, 1879. Published monthly.
Subscription fifteen dollars ($15.00) a year. Single numbers $1.50
(Foreign and Canadian postage, 50¢ additional on subscriptions)
(Copyright 1941, American Ceramic Society, Inc.)

EFFECT OF ZIRCOPAX ADDITIONS ON ABRASION RESISTANCE AND VARIOUS PROPERTIES OF SEVERAL GLAZES*

By C. H. Commons, Jr.

Abstract

A test method is described and the results of four series of experiments are given for the empirical evaluation of the effect of Zircopax in improving the resistance to abrasion of glazes. Simultaneous resistance to crazing and the effect on gloss, color, and opacity are noted.

I. Introduction

It has been known for some time that additions of Zircopax† (or another zirconium compound) to a glaze increase its chemical durability as well as its resistance to abrasion and crazing even when the amount added is less than that necessary to produce opacity. No definite data have been available, however, to show the extent to which the resistance to abrasion is affected by varying additions. By the use of a falling-sand method on enamels, originally designed by Scott,[1] Kinzie and Hake noted an improvement when ZrO_2 was incorporated. Other investigators have devised and used various tests, but these have had no effective empirical evaluation.

Inasmuch as the Porcelain Enamel Institute has developed a test procedure which seems to evaluate the abrasion resistance of materials that have specular reflection (a type of gloss), it was decided to obtain as much as possible of this type of information.

II. Procedure

Four clear glazes were used as bases to which increments of Zircopax were added. In one series, increments of silica were added in place of zirconium silicate to determine its relative effect on the glaze. The glazes, prepared in the usual manner, were sprayed on $4^1/_4$- by $4^1/_4$-in. bisque tile in duplicate and were fired on a 40-hour cycle in a laboratory continuous furnace. After notations were made on the appearance of the surfaces of the tile, they were thoroughly cleaned and tested according to the Porcelain Enamel Institute method. Two samples of each glaze, however, were used instead of four as prescribed.

The test includes (1) optically cleaning the surface of the glaze, (2) reading the specular reflection in four directions, (3) abrading the surface, and (4) reading the specular reflection after abrasion. The results are then expressed in terms of percentage of the original reflection retained after the treatment.

The abrasion treatment consists of subjecting the surface to the action of a specified weight of steel balls ($^5/_{32}$ inch in size) plus 2 gm. of a standard feldspar and 5 cc. of distilled water held in a suitable container, which is actuated by a slightly modified Ro-Tap machine for a period of time previously determined as necessary to cause a 50% loss of specular gloss on a standard polished plate glass. In this case, $8^1/_2$ minutes were required. Although this is a tentative test, it seems to produce fairly consistent results in different laboratories.

The four base glazes used have the following batch and theoretical compositions:

Batch composition of glazes

	A	B	C	D
G-14 frit	20	20	30	25
G-23 frit	30	40	25	
Keystone feldspar	25	10	30	
Flint	10	20		15
Fla. kaolin	10	10	10	10
Zinc oxide	5		3	8
Soda feldspar				30

Composition of frits

	G-14	G-23
Na_2O	10.36	6.46
CaO	20.20	
PbO		59.17
B_2O_3	23.25	14.53
SiO_2	46.15	19.84

Theoretical composition of glazes

	A	B	C	D
Na_2O	4.65	4.92	5.70	7.33
K_2O	3.05	1.22	3.81	
CaO	4.04	4.04	6.30	5.84
PbO	17.75	23.67	15.55	
ZnO	5.00		3.12	9.25
B_2O_3	10.01	11.46	11.01	6.72
Al_2O_3	8.19	5.26	9.52	10.23
SiO_2	46.62	48.86	45.18	60.63
	99.31	99.43	100.19	100.00

The empirical formulas of the glazes are as follows:

Glaze A

$$\left.\begin{matrix}0.234\ Na_2O\\ .101\ K_2O\\ .225\ CaO\\ .248\ PbO\\ .192\ ZnO\end{matrix}\right\}0.250\ Al_2O_3\left\{\begin{matrix}2.414\ SiO_2\\ 0.446\ B_2O_3\end{matrix}\right.$$

Glaze B

$$\left.\begin{matrix}0.294\ Na_2O\\ .048\ K_2O\\ .266\ CaO\\ .392\ PbO\end{matrix}\right\}0.190\ Al_2O_3\left\{\begin{matrix}2.997\ SiO_2\\ 0.605\ B_2O_3\end{matrix}\right.$$

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 2, 1941 (White Wares Division). Received October 17, 1940.

† The composition for Zircopax is ZrO_2 65.56% and SiO_2 33.44%; particle-size range, 1 to 20μ; average particle size, 10 to 15μ.

[1] W. J. Scott, "Apparatus for Measuring Abrasive Hardness of Glazes," *Jour. Amer. Ceram. Soc.*, 7 [5] 342–46 (1924).

Glaze C

$$\left.\begin{matrix}0.261\ Na_2O\\ .115\ K_2O\\ .318\ CaO\\ .198\ PbO\\ .109\ ZnO\end{matrix}\right\}0.264\ Al_2O_3\left\{\begin{matrix}2.125\ SiO_2\\ 0.446\ B_2O_3\end{matrix}\right.$$

Glaze D

$$\left.\begin{matrix}0.352\ Na_2O\\ .310\ CaO\\ .338\ ZnO\end{matrix}\right\}0.298\ Al_2O_3\left\{\begin{matrix}2.993\ SiO_2\\ 0.286\ B_2O_3\end{matrix}\right.$$

Zircopax was added to glazes A, B, C, and D in increments of 3 parts per 100 parts of the raw batch. In the case of glaze D, the additions were 3, 6, 10, 16, and 23% of Zircopax. A separate series was prepared in which 2, 4, 6, 8, 10, and 15% of flint was added to glaze D for comparison purposes. Glazes A and B were fired at 2000°F. and glazes C and D were fired at both 2050° and 1950°F., all in a tunnel kiln on a 40-hour cycle.

III. Summary of Results

(1) Glaze A Results

Glaze A produced a bright, perfectly clear glaze which was not quite fluid enough to flow out properly at this temperature. It was badly crazed within 24 hours after it was removed from the kiln. A 3% addition of Zircopax showed no apparent effect on the appearance of the glaze; the crazing, however, was reduced to such an extent that in two days only one craze mark showed on one of the pieces and the other piece showed no crazing. None of the other glazes of this series crazed spontaneously, and none was tested in the autoclave. The addition of 6% of Zircopax made the glaze slightly more fluid as shown by the fact that it flowed out a little better. A slight milkiness of incipient opacification was present, but later when it was tested with ink, the glaze appeared to be clear. Additions of 9, 12, and 15% of Zircopax did not cause any apparent changes in the surface characteristics of the glaze or in the apparent fluidity; they produced a slight but uniform opacity at 9% to a fair but not dense opacity at 15%. The original glaze had a cream color, which became lighter and more nearly white up to 15% additions, although the final glaze of this series was still a cream-white.

(2) Glaze B Results

Glaze B was nearly clear, but it had a mat to semimat surface that was not quite uniform, and it showed slight crazing (4 to 6 craze lines per tile) in 24 hours. None of the variations containing Zircopax showed any crazing. The 3% addition of Zircopax caused the glaze to become somewhat brighter and more uniform in texture; otherwise there was no apparent difference. The glaze with 6% of Zircopax became slightly brighter than that with an addition of 3%, but additional amounts showed no further change until the glaze became somewhat more mat at 18%. A definite but slight opacifying effect was noted at a 6% addition; this opacity increased progressively with each increment. The glaze had a fair opacity at 18% additions of Zircopax.

(3) Glaze C Results

Glaze C, when fired at 2050°, was bright but finely pinholed, definitely cream colored, and nearly clear. It was badly crazed within 24 hours. A 3% addition of Zircopax apparently reduced this crazing tendency only slightly, but additions of 6% or more seemed to eliminate the spontaneous crazing as none of the other pieces crazed in three weeks. There was no apparent change in the appearance of the glaze until 9% additions of Zircopax were made; the glaze then became slightly opaque and lighter in color. With each additional increment of Zircopax, the color became lighter and the glaze became more opaque. There was no apparent change in the appearance of the surface except that at 18% the glaze seemed to be slightly less bright, and the brightness again decreased a little at a 21% addition. At 21%, the glaze also seemed to be a little less fluid and pinholed.

The series fired at 1950°F. was a little brighter in appearance and a slightly lighter cream in color than when it was fired at 2050°F. The crazing tendency, however, was greater; for example, the 0% and 3% Zircopax specimens were badly crazed; the 6% specimens were appreciably better, although still badly crazed; and the 9% specimens showed slight crazing (one line on one tile and two on the other in three weeks). Glazes with additions of 12% or more of Zircopax showed no crazing in three weeks. In other respects, the results were similar to those fired at 2050°F.

(4) Glaze D Results

Glaze D, fired at 2050°F., produced an excellent smooth, bright glaze with a definite cream cast, but it was not as cream as glaze C. Because none of this series crazed in three weeks, the effect of Zircopax on this property could not be noted as these samples were used for abrasion tests and were not autoclaved. A 3% Zircopax addition had no apparent effect on the appearance of the glaze; 6% materially lightened the color and produced a definite although slight amount of opacity. Each increment of Zircopax produced materially more opacity and a whiter color. An addition of 23% produced a nearly white glaze and good opacity, but it appeared slightly cream colored when it was compared to some commercial white wall tile. This quantity of Zircopax slightly lessened the brightness of the glaze, although it was still bright with no apparent change in the surface texture.

An increase in the silica content of this glaze reduced the gloss owing to an apparent crystallization. This effect, slight at a 2% addition, became progressively more effective as each increment was added. At a 10% addition, a semimat-to-semibright glaze of slightly coarse texture was produced. It became a slightly coarse-textured, nearly mat glaze at 15% (the next increment in this case).

When the Zircopax series was fired at 1950°F., the glaze was not quite soft enough to mature properly. The glaze was bright and it had slightly less gloss than at 2050°, but it had not smoothed out as well. Additions of 3% and 6% of Zircopax did not seem to

change the maturing characteristics at all, but further increments progressively hardened the glaze until additions of 16% and higher caused the glaze to be sufficiently immature as to make abrasion tests illogical.

The effect of increments of silica was much more pronounced than that for zirconium silicate. The addition of as little as 2% of silica caused about as much effect on the refractoriness of the glaze as 16% of Zircopax and appreciably more than 10%. A 10% addition of silica caused the glaze to be so immature that it was rough to the touch and it had no gloss. None of this series was tested for abrasion resistance.

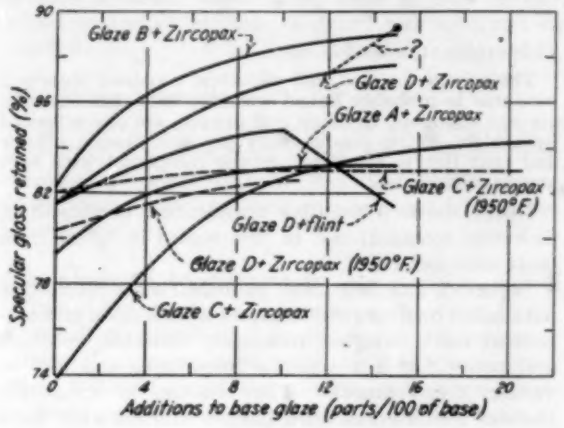


FIG. 1.

The effects on abrasion resistance are summarized in Fig. 1. Two points on the curves are questionable. A 15% addition of Zircopax in glaze D at 2050°F. seems to be abnormally high, and a 16% addition of flint in the same glaze is abnormally low. The latter may be caused by the matness of the original surface; the test, therefore, may not be applicable to mat or nearly mat surfaces.

In these same tests, however, the polished plate-glass standards which were run with each test retained a specular reflection of 50% ± 0.7%. It is also significant that the abrasion index is increased at all, inasmuch as these glazes are initially so much more resistant than glass.

IV. Conclusions

(1) The results of this series of tests with four types of glazes show that Zircopax definitely increases the resistance of the glaze to abrasion. Its effectiveness, which is more pronounced at the lower percentages, continues up to additions of 18%, although the major portion of the effective increase in abrasion index is obtained by additions of about 10%.

(2) When the glazes are underfired, there is little opportunity for the zirconium to be dissolved, and the abrasion index therefore is only slightly increased.

(3) Some empirical evaluations of the effect of Zircopax on increasing the resistance to abrasion of several glaze types have been determined.

(4) The effect is always positive throughout the field studied, but it varies somewhat with the base glaze. Both the rate of effectiveness and the total effectiveness depend to some extent on the base composition and on the firing treatment of the glaze.

(5) Flint increases the abrasion index of the glaze in which it was tried but at a lower rate than Zircopax.

(6) Previous findings of the effect of zirconium compounds, Zircopax in this case, on materially improving the crazing resistance of a glaze are corroborated.

(7) Small additions of Zircopax may either soften a glaze or make it more fluid; higher additions increase the refractoriness of the glaze. Flint is not so effective in the glaze used for comparison. This effect could be changed materially in another type of base glaze, but it is doubtful if the reverse effect would ever be noted if the glaze were originally free of zirconium dioxide.

TITANIUM ALLOY MANUFACTURING COMPANY
NIAGARA FALLS, NEW YORK

COMPOSITIONS AND PROPERTIES OF SOME HIGH-TITANIA CERAMICS*

By Louis Navias

Abstract

The compositions are given for high-titania ceramic bodies which mature at cone 10. One series contains calcium titanium silicate as an essential flux, and the other series contains alkali-free titania glasses. Electrical measurements cover the range of 60, 1000, and 1,000,000 cycles for both power factor and dielectric constant. Detailed consideration is given to the type of electrodes used. The properties covering dielectric strength, temperature coefficient of capacity, effect of humidity, and thermal expansion are given for one composition. An X-ray diffraction pattern of this body shows the formation of rutile crystals.

I. Introduction

(1) The Problem

The bonding of titania to form nonporous bodies of high dielectric constant is not a new problem. The preparation of titania bodies with fluxes maturing at cone 10, however, is a new problem, particularly when it is limited to bodies which contain no clay or bentonite.

(2) Properties of Rutile

The properties of rutile have been recorded in the literature, for instance, in International Critical Tables.[1]

Rutile	$\epsilon\perp$	$\epsilon\parallel$	ϵ_m	Frequency (cycles/sec.)
Brown	86 ± 3	170 ± 3		10^8
Transparent			78 ± 5	3×10^8
"			31	3×10^8

$\epsilon\perp$ refers to dielectric constant when direction of electric field is perpendicular to the optic axis of the crystal.
$\epsilon\parallel$ refers to parallel position.
ϵ_m refers to a mean value.

It should be noted that rutile is only one crystalline form of titania to be found in nature; rutile and anatase (octahedrite) are tetragonal and brookite is orthorhombic.

Most discussions on the dielectric loss or power factor of rutile state that the power factor is very low at radio frequencies and that such losses increase as frequency decreases. Few data are actually given for rutile but rather for ceramic bodies containing titania bonded by fluxes at high heat. The titania employed usually is a prepared, amorphous finely divided powder which crystallizes during the firing.

(3) Literature Review

Although there has been much speculation as to the reason for the high dielectric constant of rutile, no real interpretations are available. Jackson[2] gives a plausible explanation as follows:

The reason for the high dielectric constant possessed by rutile is probably linked with the fact that the constituent elements, titanium and oxygen, are characterized by a high electric polarizability per unit atomic volume and that this is associated in the compound with high atomic polarization.

Rutile shows a negative temperature coefficient of dielectric constant, and in this regard it differs from most solid dielectrics.

Berberich and Bell[3] have published some interesting data taken on fired rutile samples as well as on ceramic-bonded rutile samples, measuring dielectric constant and power factor at various frequencies and also at various temperatures. They discuss in detail the theories which Frank[4] and Eucken and Büchner[5] have proposed to explain the high dielectric constant of rutile (mean D. C. 114) as against the lower values for brookite, 78, and for anatase, 31. They conclude that the high dielectric constant of rutile is accounted for by a high refractive index coupled with a normal atomic polarizability. The electronic and atomic polarizabilities are discussed in detail.

Soyck[6] showed that the dielectric constant of titania bodies increases rapidly as the titania content is increased, and he also pointed out the relative dependence on temperature of the dielectric constants of these same compositions (Fig. 1). The changes of power factor with frequency for one of Soyck's compositions as well as for Condensa C are reproduced in Fig. 2.

II. Procedure

(1) Size of Specimen

The aim was to obtain specimens on which measurements for dielectric constant and power factor could be made with some degree of accuracy, and preliminary work indicated that fairly large disks were necessary. Owing to the high firing shrinkage of most of the bodies,

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 3, 1941 (White Wares Division). Received February 4, 1941.

[1] International Critical Tables, Vol. VI, p. 99 (1929).

[2] Willis Jackson, "Recent Progress Toward Correlation of Chemical Composition, Physical Constitution, and Electrical Properties of Solid Dielectric Materials," *Jour. Inst. Elec. Engrs.* [London], **79**, 565–76 (1936); *Chem. Abs.*, **31**, 6070 (1937); *Ceram. Abs.*, **17** [2] 65 (1938).

[3] L. J. Berberich and M. E. Bell, "Dielectric Properties of the Rutile Form of Titanium Oxide," *Jour. Applied Phys.*, **11**, 681–92 (1940).

[4] F. C. Frank, "On High Dielectric Constants," *Trans. Faraday Soc.*, **33**, 513–23 (1937).

[5] A. Eucken and A. Büchner, "Die Dielektrizitätskonstante schwach polarer Kristalle und ihre Temperaturabhängigkeit," *Z. physik. Chem.*, **B27**, 321–49 (1934).

[6] Werner Soyck, "Eigentumlichkeiten des dielektrischen Verhaltens rutilhaltiger Kondensator-Baustoffe," *Ver. deut. Elektrotech. Fachberichte*, pp. 129–32 (1935).

it was necessary to press the material in a 6-in. mold in order to obtain a fired disk, $4^1/_2$ in. in diameter and $^1/_4$ in. thick. Disks of smaller diameter were also made and measured.

(2) Pressing Operation

The finely divided materials were ball-milled in water, filter-pressed, and thoroughly dried. Moisture was then added in definite amounts, and the powder was pressed in a hardened steel mold, using a pressure of 20 to 25 tons. Numerous trials with organic binders, such as paraffin wax introduced as a carbon tetrachloride solution, showed that these organic binders, which caused an increase in power factor, should be avoided.

(3) Firing Schedule

Short laboratory firings were not so effective as a long firing in a commercial tunnel kiln used for firing electrical porcelain to cone 10. The lowest power-factor values were obtained on specimens fired in the tunnel kiln.

(4) Electrical Measurements

Two different methods were used for most of the electrical measurements* depending on the frequency range. Guard rings were used only in a few measurements to be described later; otherwise no edge corrections were made. Measurements were usually made at 60 cycles, at 1 kc., and at 1000 kc., although the main purpose was to obtain bodies with a low power factor near 1000 kc.

* Most of the electrical measurements were made by R. N. Bushman.

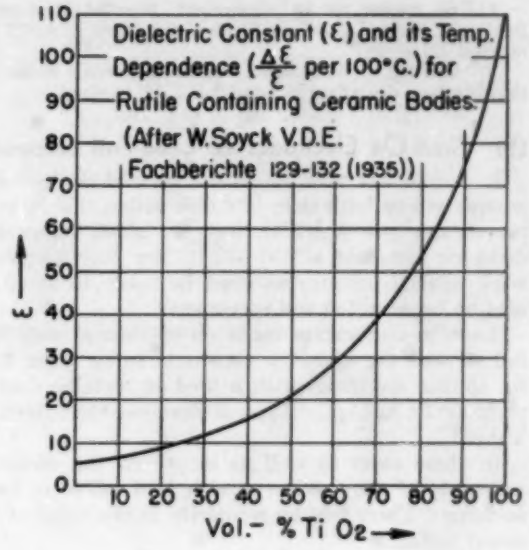

Dielectric Constant (ε) and its Temp. Dependence ($\frac{\Delta\varepsilon}{\varepsilon}$ per 100°C.) for Rutile Containing Ceramic Bodies (After W. Soyck V.D.E. Fachberichte 129-132 (1935))
ε
Vol.- % Ti O2
$\frac{\Delta\varepsilon}{\varepsilon}$ / 100°C
Vol.- % Ti O2

FIG. 1.

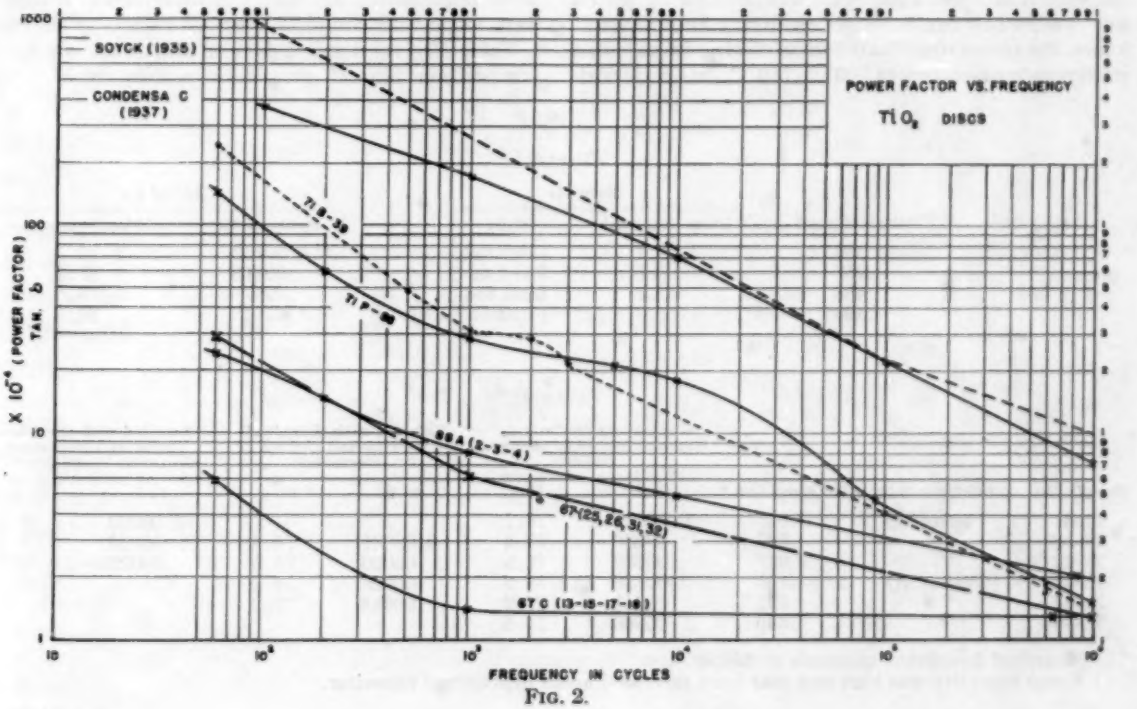


FIG. 2.

(1) 60 cycles to 10 kilocycles: Parallel Resistance Bridge or Series Resistance Bridge, described in A.S.T.M. method D150–36T.
(2) 100 kc. to 1000 kc.: Resonant Circuit Substitution Method, described in same A.S.T.M. method.

(5) Fired-On Electrodes vs. Lead-Foil Electrodes

It is common practice to use metal-foil electrodes compressed on both sides of a disk with a thin layer of petrolatum (see A.S.T.M. tests for power factor and dielectric constant, D150–39T). For high-frequency work, special precautions must be taken to avoid an air film between foil and specimen.

Some measurements made on specimens with lead foil showed the dielectric constants to be lower than for similar specimens with a fired-on metallic coating such as Pt-Au(Ag). Typical examples are given in Table I.

In these cases as well as in others, the dielectric constants of the specimens with lead foil were lower in value. There was no regularity in the value of the power factor.

It was estimated that at 750 to 1000 kc., the power-factor measurements would be in error by ±30% for lead electrodes and by ±15% for the fired-on electrodes. The dielectric constants likewise would be in error by ±10% for the lead electrodes and by ±5% for the fired-on electrodes.

For these reasons, each side of all of the specimens was given a fired-on coating of Pt-Au, onto which a thin layer of Ag was electroplated; the entire process was designated Pt-Au(Ag).

(6) Fired Pt-Au Metallic Coating

DuPont L.B. silver, which is mainly an organic suspension of Pt and Au salts, was brushed on with a fine camel's hair brush. After air-drying for at least 12 hours, the pieces were heated in an electric furnace to a maximum temperature of 700° to 750°C., at an approximate rate of 100°C. per hour. The fired coating has an unpolished, metallic gray appearance on a vitrified body. A porous body will show little or no metallic sheen.

(7) Electroplating

Silver can be deposited on the fired coating to a depth of about ½ mil from a bath, using 1 volt potential for about 6 to 8 minutes. Each gallon of the electroplating solution contained silver cyanide 3 oz., sodium cyanide 4 oz., and sodium carbonate 2 oz. Heavier silver coats will peel off taking the Pt-Au with it.

(8) Ni vs. Ag Plating on Pt-Au Fired Coating

Some disks were electroplated with Ni (instead of with Ag) over the fired-on Pt-Au coating. Using ordinary sized contact electrodes, the samples with Ni gave consistently higher values of power factor than were obtained with the Ag coatings.

Typical data are given for specimens of composition No. 71, pressed in a 6-in. mold. The total shrinkage amounted to 27%, the disks were 0.640 cm. thick, and the area of the fired-on electrodes was 46 sq. cm.

No. of disks	Electrodes	1000 kc. (P. F.)	1000 kc. (D. C.)
3	Pt-Au(Ag)	0.00039	75.5
3	Pt-Au(Ni)	.00079	76.7

This difference was found later to be due to the greater electrical resistance of the Ni film as compared with the Ag film; comparable results could be obtained if the entire electrode areas on both sides of the disk were covered with a thick conducting sheet, such as lead sheet, on which the smaller contact electrodes were impressed. All later measurements therefore were made with complete sheet-lead backing plates.

Table II gives detailed data on individual samples of composition No. 71 pressed in a 6-in. mold. The

TABLE I

Composition	Thickness (cm.)	Electrode: Area (sq. cm.)	Electrode: Type	At 750 kc.: Power factor	At 750 kc.: Dielectric constant
50*c*	0.255	20.3	Lead foil	0.00152	73.7
	.257	17.7	Fired on	.00115	87.8
51*b*	.463	20.3	Lead foil	.0267	73.5
	.460	17.0	Fired on	.0314	76.5

TABLE II*

Sample No.	Electrode type	Thickness (cm.)	Contact electrodes only (samples heated in oven and cooled): P. F.	Contact electrodes only (samples heated in oven and cooled): D. C.	Retested with sheet-lead backing and contact electrodes: P. F.	Retested with sheet-lead backing and contact electrodes: D. C.	Retested with sheet-lead backing and contact electrodes (humidity 60%): P. F.	Retested with sheet-lead backing and contact electrodes (humidity 60%): D. C.†
71-31	Pt-Au(Ag)	0.646	0.00032	76.7			0.00020	76.5
71-32	"	.627	.00036	74.4	0.00021	74.4	.00026	74.0
71-43	"	.647	.00030	75.5	.00020	75.5	.00022	75.1
71-41	Pt-Au(Ni)	.655	.00136	78.5	.00026	78.7		
71-44	"	.642	.00041	77.2	.00018	77.2		
71-49	"	.640	.00060	74.5				

* Electrical measurements made at 650 kc.
† Room humidity was high and may have increased losses in standard capacitor.

TABLE III

	Body No.					
	62	67	69	71	86	87
TiO_2 (%)	90	90	90	90	90	90
Calcium titanium silicate (%)	10	5	5	3.4	7.5	7.5
MgO		5		3.4		2.5
BeO			5	3.4	2.5	
Disks						
Diameter (cm.)	5.7	5.7	5.7	5.7		
Thickness (cm.)	0.576	0.618	0.596	0.617		
Electrode						
Area (sq. cm.)	10.0	10.0	10.0	10.0		
Type	Pt-Au(Ag)	Pt-Au(Ag)	Pt-Au(Ag)	Pt-Au(Ag)		
No. of samples	3	5	6	2		
At 1000 kc.						
P. F.	0.00095	0.00024	0.00047	0.00036		
D. C.	108.8	78.9	98.0	85.8		
Disks						
Diameter (cm.)	11.4	11.4		11.4	11.4	11.4
Thickness (cm.)	0.580	0.646		0.640	0.597	0.610
Electrode						
Area (sq. cm.)	46	46		46	46	46
Type	Pt-Au(Ag)	Pt-Au(Ag)		Pt-Au(Ag)	Pt-Au(Ag)	Pt-Au(Ag)
No. of samples	3	5		3	4	2
At 650–1000 kc.						
P. F.	0.00060	0.00038		0.00039	0.00080	0.00022
D. C.	98.6	70.9		75.5	88.0	85.6

TABLE IV

	Body No.						
	73	75	77	82	79	88	89
TiO_2 (%)	95	90	95	93	90	93	93
Glass (%)	5	10	5	7	10	7	7
	Glass No.						
Glass composition (%)	490	490	491	491	491	513	516
SiO_2	72	72	39.8	39.8	39.8	33.6	18
B_2O_3	20	20					
TiO_2	8	8	16.8	16.8	16.8	29.8	15
Al_2O_3			13.8	13.8	13.8	11.6	2
CaO			29.6	29.6	29.6	25.0	
PbO							65
Disks							
Diameter (cm.)	5.7	5.7	5.7		5.7		
Thickness (cm.)	0.590	0.610	0.579		0.578		
Electrode							
Area (sq. cm.)	10.0	10.0	10.0		10.0		
Type	Pt-Au(Ag)	Pt-Au(Ag)	Pt-Au(Ag)		Pt-Au(Ag)		
No. of samples	3	3	4		4		
1000 kc.							
P. F.	0.0017	0.0010	0.00036		0.00031		
D. C.	103.3	85.3	113.5		104.0		
Disks							
Diameter (cm.)			11.4	11.4	11.4	11.4	11.4
Thickness (cm.)			0.581	0.585	0.545	0.571	0.566
Electrode							
Area (sq. cm.)			46.6	46.0	46.0	46.0	46.0
Type			Pt-Au(Ag)	Pt-Au(Ag)	Pt-Au(Ag)	Pt-Au(Ag)	Pt-Au(Ag)
No. of samples			2	3	2	4	3
650–1000 kc.							
P. F.			0.00058	0.00036	0.00052	0.00021	0.00034
D. C.			101.0	98.0	89.5	101.7	101.8

area of the fired-on electrode in each case was 46 sq. cm. Ordinary contact electrodes were 5 sq. cm. in area. The lead sheeting, 1/16 in. thick and cut in circles, was used as backing for electrodes where it was required. The electrical measurements were made at 650 kc.

The use of Ni was abandoned because it was discovered that a disk with Pt-Au(Ni) fired electrodes would not allow oscillation at 1420 kc. or above. A similar disk with Pt-Au(Ag) fired electrodes was not so limited.

III. Compositions of Titania Bodies

(1) Calcium Titanium Silicate[7] as Flux

The mineral titanite, $CaO \cdot TiO_2 \cdot SiO_2$, may be used as a flux for titania.*

Table III gives the compositions and electrical data on several bodies.

The apparent effect of the size of the sample on measurements is interesting and will partially explain how difficult it is to correlate such data from several sources where size of sample, size of electrodes, and the kind of contacts are not known. It is obvious that good relative results may be obtained by holding all conditions constant and by varying only the compositions of the body.

(2) Alkali-Free Titania Glasses[8] as Flux

It is possible to use some glasses as ceramic binders for titania. Three main types are described here, and the composition of the glasses is given in Table IV.

(*A*) *Glass No. 490:* Bunting[9] gives a eutectic at 1540°C. for the mixture containing TiO_2 10.5% and SiO_2 89.5%. A melt of TiO_2 10% and SiO_2 90% in platinum at 1580°C. was unsuccessful. At best there was hardly any sintering. The addition of a large amount of B_2O_3, as used in glass No. 490, gave an opaque glass at 1500°C. The glass actually consists of at least two glasses, immiscible in each other. The glass was crushed, ball-milled, and used in mixtures in the regular manner.

(*B*) *Glasses Nos. 491 and 513:* In a study of the ternary system anorthite–titanite–wollastonite, Iwasé and Nisioka[10] report a ternary eutectic at 1240°C., having the composition of anorthite ($CaO \cdot Al_2O_3 \cdot 2SiO_2$) 37.5, titanite ($CaO \cdot TiO_2 \cdot SiO_2$) 25.0, and wollastonite ($CaO \cdot SiO_2$) 37.5% by weight, which corresponds to the oxide formula of SiO_2 43.3, Al_2O_3 13.8, TiO_2 10.2, and CaO 32.8%.

These three minerals, in the proportions of the eutectic, were used to the extent of 5.4% as a binder for TiO_2. Large disks, pressed in the usual manner and fired to cone 10 in the tunnel kiln, were found to be quite porous.

Glass No. 491, which has a composition somewhat near that of the eutectic, was made by melting glass-batch ingredients in platinum. The glass is colored brown and crystallizes rapidly unless it is chilled. In glass No. 513, the proportions of SiO_2, Al_2O_3, and CaO were maintained as in the eutectic composition, but the TiO_2 content was increased.

Both of these glasses were found to be effective as fluxes for titania.

(*C*) *Glass No. 516:* Hirose and Kamogawa[11] have described lead glasses containing TiO_2 which have high dielectric constants. One of their glasses, given on a weight percentage basis as glass No. 516, was found to be satisfactory for the purpose at hand. The melt is fluid and can be poured as such although the glass crystallizes readily when it is reheated.

IV. Power Factor at Frequencies of 60 and 1000 Cycles

The data in Table V are given for measurements at 60 and 1000 cycles. The data at 1000 kc. have been taken from Tables III and IV to complete the sets. Measurements are given only of the large disks which were equipped with fired-on Pt-Au(Ag) electrodes.

From an inspection of the power factor at 1000 kc., there is no guide whereby the power factor at 60 cycles can be predicted. Figure 2 shows the data for compositions Nos. 67, 71, and 88.

The dielectric constant is practically unaffected by frequency in the range discussed here.

V. Edge Correction

(*a*) All electrical measurements reported in this paper were made on disks with fairly large electrodes, no edge correction being made. As late as January, 1939, the A.S.T.M. test method D150–36T shows curves for the calculation of edge correction for materials having dielectric constants from 1 to 10. These corrections do not apply to materials having a dielectric constant of an entirely different order of magnitude, such as 60 or 80. The work of Scott and Curtis,[12] however, has given new equations whereby edge corrections may be made for disks of materials, including titania compositions that have high dielectric constants. These are incorporated in A.S.T.M. test method D150–39T.

(*b*) To determine the edge correction, one disk was measured* by using lead foil electrodes of different

[7] Louis Navias (General Electric Co.), "Ceramic Material," U. S. Pat. 2,220,774, Nov. 5, 1940; *Ceram. Abs.*, **20** [1] 21 (1941).

* In practice, a synthetic product of the Titanium Alloy Mfg. Company was used; the analysis of the grade A material is CaO 28.3, TiO_2 40.5, SiO_2 30.3, Fe_2O_3 0.1, and undetermined 0.8%.

[8] Louis Navias (General Electric Co.), U. S. Pat. 2,220,775, Nov. 5, 1940.

[9] E. N. Bunting, "Phase Equilibria in the Systems TiO_2, TiO_2–SiO_2, and TiO_2–Al_2O_3," *Bur. Stand. Jour. Research*, **11** [5] 719–25 (1933); *Ceram. Abs.*, **13** [3] 71 (1934).

[10] Keizô Iwasé and Usaburô Nisioka, "Equilibrium Diagram of the Ternary System Anorthite–Titanite-Wollastonite," *Science Repts. Tôhoku Imp. Univ., Series 1, Honda Anniversary Vol.*, pp. 444–53 (Oct., 1936); *Ceram. Abs.*, **16** [5] 161 (1937).

[11] Mitsuo Hirose and Hiroshi Kamogawa (General Electric Co.), "Vitreous Materials," U. S. Pat. 2,220,765, Nov. 5, 1940; *Ceram. Abs.*, **20** [1] 16 (1941).

[12] A. H. Scott and H. L. Curtis, "Edge Correction in Determination of Dielectric Constant," *Jour. Research Nat. Bur. Stand.*, **22** [6] 747–75 (1939); R.P. 1217.

* Measurements by S. I. Reynolds.

TABLE V

Composition No.	No. of samples	Power factor 60 c.	Power factor 1 kc.	Power factor 1000 kc.*	Dielectric constant 60 c.	Dielectric constant 1 kc.	Dielectric constant 1000 kc.*
62B	3	0.0060	0.0031	0.00060			98.6
67C	4	.00058	.00014	.00013			74.4
69A	5	.028	.0026	.00047		97.9	98.0
71P	4	.015	.0028	.00017	75.5	75.5	75.5
77B	3	.0078	.0018	.00058		100.7	101.0
79C	2	.0060	.0033	.00052			89.5
82G	3	.016	.0015	.00036			98.0
86A	2	.017	.0067	.0008			88.0
87A	2	.0021	.0034	.00022			85.6
88A	3	.0025	.00081	.00021	102	102	101.7
89A	3	.0032	.0014	.00034			101.8

* From 650 to 1000 kc.

areas, with and without guard rings. The Bridge method, essentially described in A.S.T.M. test method D150, was used. The actual capacities measured are given as well as the calculated dielectric constants, and the data are given in Table VI and also plotted in Fig. 3.

TABLE VI

Specimen No. 71 C-47; diameter 11.1 cm.; area 990 sq. cm.; thickness 0.649 cm.

1000 kc. lead-foil electrode (sq. cm.)	With guard rings μμf.	With guard rings D.C.	Without guard rings μμf.	Without guard rings D.C.
96.4	892	66.0	892	66
49.0	437	67.3	520	71
19.6	175	68.4	228	75
6.2	56	66.5	85	85
Average		67.1		

The change in electrode area with guard rings caused a variation of dielectric constant of between 66.0 and 68.4, whereas without guard rings the dielectric constants varied between 66 and 85. As most of the larger disks mentioned in this report were fitted with electrodes having an area of about 47 sq. cm., the dielectric constants determined by measuring the capacity without guard rings would be too high by about 4 if lead electrodes were used. The use of fired-on electrodes (without guard rings), however, gives higher readings of dielectric constant as shown in Table I.

(*c*) Another sample, No. 71 P-89, equipped with fired-on Pt-Au(Ag) electrodes, was measured for power factor by three individuals to compare the unguarded sample with a guarded sample. The data are given in Table VII and Fig. 4. The curves show that there is not much difference in the value of the power factor except in the range of 100 kc. where the guarded sample shows a much lower value. These values were checked and were found to be valid.

VI. Effect of Humidity on Electrical Measurements

One set of disks was measured when it was thoroughly dry and also when it was subjected to 60% of humidity. The electrical characteristics were modified only slightly, but owing to the effect of humidity on

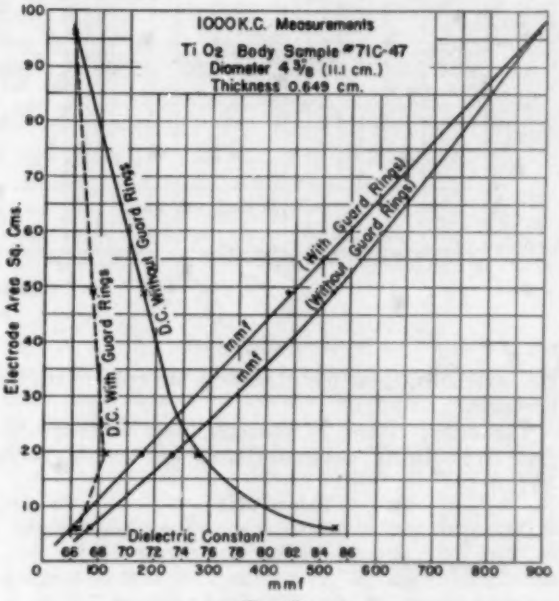


FIG. 3.

TABLE VII

Specimen No. 71 P-89; thickness 0.597 cm.; Pt-Au(Ag) electrode, 46 sq. cm.; diameter 11.4 cm.

Cycles	Power factor Unguarded	Power factor Unguarded	Power factor Guarded
20			0.037
27			.030
34			.023
44			.020
60	0.014	0.017	.017
78			.015
200	.0060	.0068	.0068
Kilocycles			
1	.0028	.0027	.0030
2			.0024
5	.0019	.0022	.0023
8			.0019
10	.0016	.0019	.0018
50	.00070		
90	.00044		
100	.00040	.00044	.00019
500	.00020		
1000	.00015	.00023	.00017

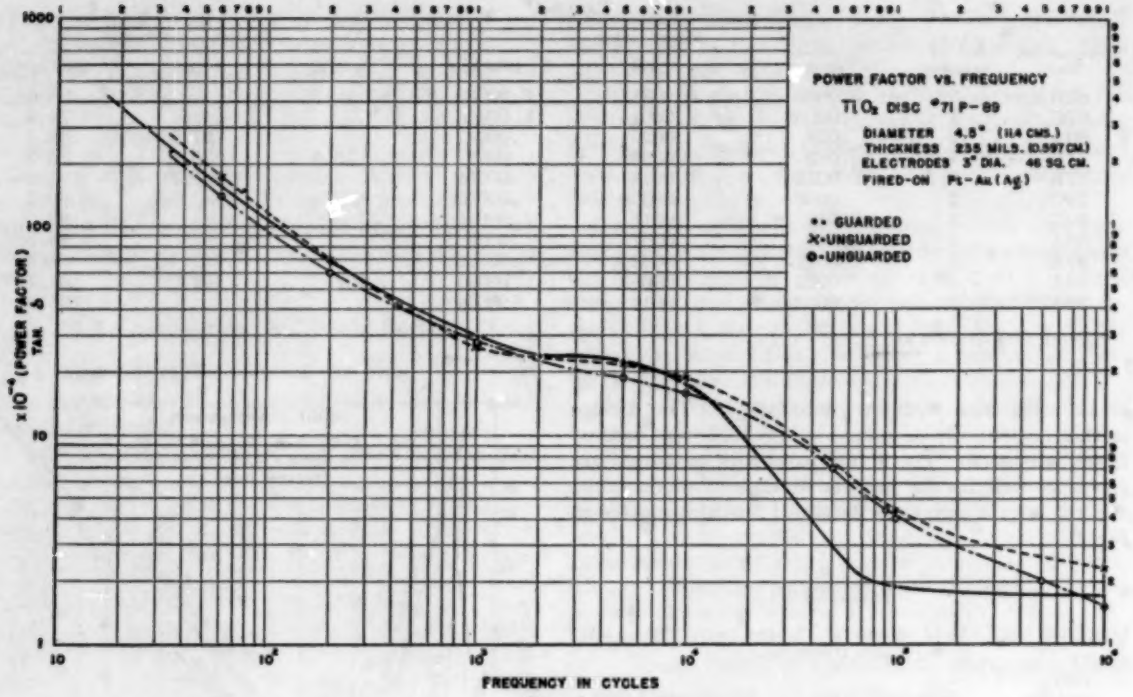


FIG. 4.

the standards, these measurements are only relatively accurate.

The disks, 11 cm. in diameter, were covered with fired-on Pt-Au(Ag) electrodes, 46 sq. cm. in area (Table VIII).

TABLE VIII

Sample No.	Thickness (cm.)	Dry (at 650 kc.) P.F.	Dry (at 650 kc.) D.C.	Humidity (80%) (at 650 kc.) P.F.	Humidity (80%) (at 650 kc.) D.C.
71B-31	0.646	0.00032	76.6	0.00020	76.5
-32	.627	.00036	74.4	.00026	74.0
-43	.647	.00030	75.5	.00022	75.1
-39	.640	.00023		.00023	

VII. Dielectric Strength

(*a*) Plates were punctured with 60-cycle a.c. under oil, using 1-in. disk electrodes.

Composition No.	No. of specimens	Thickness (mils)	Breakdown voltage (kv.) Min.	Breakdown voltage (kv.) Max.	Dielectric strength (v./mil) Min.	Dielectric strength (v./mil) Max.
71	2	248	33.5	38.0	135	153
77	2	230–234	29.5	32.0	127	137
79	12	207–229	25.0	37.0	116	161
				(12) average	139	

(*b*) A specimen of No. 71, fitted with annular corona shields, was punctured in air with 60-cycle a.c.; 30 kv. were required to break through the specimen that was 211 mils thick. The breakdown strength in air is 142 volts per mil.

VIII. Temperature Coefficient of (Electrical) Capacity

The capacity of composition No. 71 decreases as the temperature rises and the temperature coefficient, which is negative, amounts to −0.07% per 1°C.

IX. Thermal Expansion of Composition No. 71

Disk No. 71 A-3, pressed in a 6-in. mold and fired in the tunnel kiln, was cut by a diamond saw into a rod 4.28 in. long. The expansion was measured* in an apparatus using a standard of similar length for comparison. The thermal linear expansion between 100° and 500°C. is 7.2×10^{-6}.

X. X-Ray Diffraction Patterns of TiO_2 Compositions

Rutile has been known for some time to be the stable high-temperature form of TiO_2.[9] A few X-ray diffraction powder patterns were taken of some materials used in this investigation in the raw and fired states to follow the development of crystallization. Each powdered substance was compared with NaCl as a standard.†

The axial ratios of the TiO_2 minerals vary considerably from each other as follows:

TiO_2	Crystal form	Axial ratios (*a*)	Axial ratios (*b*)	Axial ratios (*c*)
Rutile	Tetragonal	1	1	0.644
Anatase	Tetragonal	1	1	1.777
Brookite	Orthorhombic	0.842	1	0.944

A pigment grade of TiO_2, used as a source of TiO_2 in these compositions, gave diffraction lines which could not be determined. The powder showed only the rutile structure when fired to 1300°C. Composition No. 71, which contains the same type of TiO_2 and 10% of fluxes, showed definitely the development of rutile crystals when it was fired. These diffraction patterns

* Measurements made by E. E. Burger.
† Measurements made by L. L. Wyman.

were also found to be similar to those obtained from powdered rutile in both the raw and fired states (1300°C. in oxygen).

Acknowledgment

It is a pleasure to give credit to M. R. Many and Leo Cummings for their persistent labor in carrying out the ceramic development. In addition to those mentioned in the paper, there are others too numerous to recognize here, who have contributed in one way or another to make this report possible.

Research Laboratory
General Electric Company
Schenectady, New York

STUDY OF EUTECTIC FLUXES IN SEMIVITREOUS AND VITREOUS WHITEWARE BODIES*

By C. R. Austin and S. J. Brooks

Abstract

Frits of oxides of lithium, barium, calcium, and magnesium combined with calcined alumina and pulverized flint were substituted for feldspar in a dry-press whiteware body. Three series of bodies were studied which contained (1) about one half the normal RO content, (2) the normal RO content, and (3) about three times the normal RO content. Firing behavior and mechanical properties of the various bodies in the vitreous and semivitreous range were determined, and the results are reported in this paper.

I. Introduction

This investigation was undertaken to determine the effect of replacing feldspar with fritted fluxes of eutectic compositions in dry-pressed whiteware bodies of the vitreous and semivitreous types. It is a continuation of an investigation on fluxes in whiteware bodies, the results of which have not yet been published. The natural fluxes, such as feldspar, Cornwall stone, talc, nepheline syenite, and others, have been used widely in ceramic bodies, but the demand for improved bodies with special properties has stimulated interest in other fluxes.

The use of a fritted material as the fluxing agent in a ceramic body probably dates back to the early French "pâte tendre" ware which contained about 30% of a frit made from saltpeter, chalk, and flint. A more recent application of this type of fluxing agent was made in Belleek ware of English origin which contains about 50% of a frit made from feldspar, whiting, and flint. Later investigations[1] have followed along this line, that is, the frits have consisted primarily of feldspar with various additions, such as dolomite, whiting, and bone ash. Numerous studies[2] have also been made on the effects of small additions of magnesite, whiting, talc, barite, and lepidolite to the normal feldspar body. This type of addition has been considered as an "auxiliary flux."

Fritted fluxes of eutectic compositions were used in the present investigation to replace the feldspar entirely so that their effects, per se, might be investigated. Time did not permit a study of combinations of various "artificial" and "natural" fluxes.

II. Experimental Work

(1) Preparation of Frits

The calculated compositions of the frits, approximate melting temperatures, sieve analyses, chemical analyses, and source of the information on the eutectic compositions are given in Table I.

The frits were melted at temperatures of 2500° to

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 3, 1941 (White Wares Division). Received October 2, 1940.

Work done on a Battelle Memorial Institute fellowship and based on a thesis submitted by S. J. Brooks in partial fulfillment of the requirements for the degree of M.Sc. in Ceramic Engineering, The Ohio State University, Columbus, Ohio, June, 1939.

[1] (*a*) P. F. Collins, "Study of China Bodies of Belleek Type," *Jour. Amer. Ceram. Soc.*, **11** [9] 706–12 (1928).

(*b*) P. F. Collins, "Auxiliary Fluxes in Ceramic Bodies," *ibid.*, **15** [1] 17–27 (1932).

(*c*) G. A. Loomis, "Use of Auxiliary Fluxes in Dinnerware Bodies," *ibid.*, **16** [8] 356–59 (1933).

[2] (*a*) R. F. Geller and A. S. Creamer, "Talc in Whiteware Bodies of Wall-Tile Type," *ibid.*, **18** [9] 259–69 (1935).

(*b*) Donald Hagar, "Effect of Tremolitic Talc in Whiteware Bodies," *ibid.*, **19** [1] 14–23 (1936).

(*c*) H. Z. Schofield, "Study of Replacement of Cornwall Stone by Talc and Feldspar in a Wall-Tile Body," *Bull. Amer. Ceram. Soc.*, **16** [5] 203–204 (1937).

(*d*) Ralston Russell, Jr., "Auxiliary Fluxes in Combination with Different Feldspars in an Earthenware Body," *Ceram. Age*, **26** [6] 219–21 (1935); *Ceram. Abs.*, **17** [4] 147 (1938).

(*e*) C. M. Lampman, "Lepidolite as Flux in Whiteware Bodies," *Ceram. Ind.*, **33** [6] 40 (1939); *Ceram. Abs.*, **19** [2] 49 (1940).

TABLE I
FRIT COMPOSITIONS AND SIEVE ANALYSES

Frit	Eutectic composition Ingredient	(%)	Chemical analysis (%)*	P.C.E.	Sieve analyses† Cumulative % retained on sieve 200-mesh	275-mesh	325-mesh
Barium‡	BaO	35	32.1				
	Al_2O_3	10	10.5	6	5.2	9.0	10.3
	SiO_2	55	57.3				
Magnesium§	MgO	20.3	18.2				
	Al_2O_3	18.3	19.8	13	2.8	3.3	4.1
	SiO_2	61.4	62.0				
Calcium‖	CaO	23.3	24.0				
	Al_2O_3	14.7	15.0	3–4	3.4	8.7	13.7
	SiO_2	62.2	60.8				
Lithium¶	Li_2O	13.0	11.7				
	Al_2O_3	22.0	24.3	08–07	1.5	4.2	7.7
	SiO_2	65.0	64.0				

* Analytical Laboratory, Battelle Memorial Institute.
† U. S. standard sieves.
‡ A. S. Watts, "Deformation Study of BaO–Al_2O_3–SiO_2 Mixtures," *Trans. Amer. Ceram. Soc.*, **19**, 457–59 (1917).
§ F. P. Hall and Herbert Insley, "Compilation of Phase-Rule Diagrams of Interest to Ceramist and Silicate Technologist," *Jour. Amer. Ceram. Soc.*, **16** [10] 455–567 (1933); Fig. 94, p. 526.
‖ *Ibid.*, Fig. 92, p. 524.
¶ R. Ballo and E. Dittler, "Binary Systems Li_2SiO_3:$Al_2(SiO_3)_3$, $LiSiO_4$:$Al_4(SiO_4)_3$, $LiAlO_2$:SiO_2 and Lithium-Aluminum Silicate Minerals," *Z. anorg. Chem.*, **76**, 39–69 (1912).

2700°F. and were poured into water. The water-quenched frits were dry-ground in laboratory-size ball mills until less than 14% of the sample remained on a U. S. standard 325-mesh sieve.

(2) Body Compositions

The composition of the base body, designated as body No. 2, in which the various frits were incorporated, was as follows:

Ingredient	(%)
Keene feldspar	6.0
Genesee feldspar	3.0
Ky. No. 4 ball clay	29.5
N. C. kaolin	25.5
Flint	36.0

The molecular formula calculated from the batch composition and analyses of the feldspars was as follows:

$$\left.\begin{matrix} 0.0176\ Na_2O \\ 0.0470\ K_2O \\ \hline RO^* = 0.0646 \end{matrix}\right\} 1.00\ Al_2O_3 \quad 4.92\ SiO_2$$

* In calculating the RO, only the alkali content of the feldspar was used.

The various fluxes were substituted on a stoichiometric basis for the 0.0646 RO content of the base body. The compositions of the various bodies are given in Table II. Bodies in the "H" series contained approximately three times the RO content of the base body, the "N" series an equal RO content, and the "L" series approximately one half the RO content.

(3) Preparation of Bodies

The batch was mixed as a thick slurry with about 50% of water in a 5-liter Abbé laboratory ball mill for 2 hours with an 800-gm. charge of balls. The resulting slurry was dried at 120°F. to the bone-dry state, crushed to pass a 20-mesh sieve, tempered with 10% of water, aged several days, and again passed through a 20-mesh sieve. The batch was then aged at least 3 days in an airtight container to insure uniform distribution of the moisture.

(4) Forming Procedure

The correct amount, by weight, of material for each specimen was placed in the proper mold, leveled off with a metal template, and pressed at 1500 lb. per sq. in. in a hand-operated hydraulic press. Specimens, 3 by 1 in. and $^3/_8$ in. thick, were used to determine firing shrinkage, fired absorption, and impact and transverse strength. Specimens used in the sag test were $7^3/_8$ by $1^3/_8$ in. and $^3/_8$ in. thick. Translucency test wedges were made by grinding a dry tile, 3 by 1 in., on an abrasive grinding wheel to a wedge shape with a minimum thickness of 0.01 in.

TABLE II
BATCH COMPOSITIONS OF BODIES

Body	Ingredients (%) Keene feldspar	Genesee feldspar	Frit	Ky. ball clay	N. C. kaolin	Flint
No. 2	6.0	3.0		29.5	25.5	36.0
Clay-flint				32.4	28.0	39.6
L-lithium			5.9	30.8	26.8	36.6
L-barium			11.1	31.0	26.8	31.1
L-calcium			6.0	31.6	27.2	35.2
L-magnesium			4.9	31.4	27.1	36.6
N-lithium			11.2	29.0	25.3	34.5
N-barium			20.0	28.0	24.0	28.0
N-calcium			11.4	29.7	25.7	33.2
N-magnesium			9.5	30.0	25.7	34.8
H-lithium			27.3	23.7	20.7	28.3
H-barium			42.8	19.9	17.3	20.0
H-calcium			27.9	24.3	20.8	27.0
H-magnesium			23.8	25.2	21.7	29.3

(5) Effect of Various Firing Schedules

Duplicate sets of tile were fired to cone 11[3] in a laboratory kiln on a 10-hour schedule and to cone 11[3] in a gas-fired commercial periodic kiln on a 96-hour schedule to determine the effect of various firing treatments on the bodies studied.

TABLE III

PROPERTIES OF BODIES FIRED IN A COMMERCIAL KILN* AND IN A LABORATORY KILN† TO CONE 11[3]

Body	Linear shrinkage (%)		Absorption (%)		Transverse strength (lb./sq. in.)	
	*	†	*	†	*	†
No. 2	6.2	7.1	8.2	5.9	3800	4700
N-barium	3.7	7.1	13.9	7.1	3100	4750
N-lithium	2.4	7.0	15.0	6.5	2350	4550
N-calcium	1.8	3.0	17.0	15.1	2350	3250
N-magnesium	2.4	3.8	17.9	14.9	2500	3700

* 96-hr. commercial run.
† 10-hr. laboratory run.

The results are given in Table III. Bodies fired in the commercial kiln had a lower firing shrinkage, lower transverse strength, and greater absorption than similar bodies fired in the laboratory kiln on the shorter schedule. These results indicate an advanced state of vitrification in bodies fired on the 10-hour schedule, especially when the fluxing agent is active at the firing temperature. These results agree with observations previously reported by Watts.[3]

Owing to limited time and facilities, the firing schedules described in detail in the following paragraphs were used throughout the investigation, and interpretation of data was based on the results obtained by using the laboratory firing schedules.

(6) Firing Procedures

The general characteristics of the various bodies were determined by a series of draw-trial runs from cones 5 to 15 which were made in a gas-fired Bellevue semimuffle furnace. The temperature of the furnace was raised to 1900°F. in 18 hours and then at the rate of about 50°F. an hour to cone 15. The tile were placed as soon as they were drawn in an electric furnace at 1800°F. and were cooled to room temperature in 24 hours.

The final runs were made in a laboratory gas-fired, high-temperature kiln which was heated at the rate of 100°F. per hour until the desired cone started to deform. This temperature was then maintained to allow approximately a 1½-hour soaking period before the cone fell.

(7) Testing Procedure

Firing shrinkage, fired water absorption, and transverse strength were determined by the standard procedures.

Impact tests were made on a Charpy-type machine having a 1.05-lb. hammer and a maximum blow of 1.92 ft.-lb. The distance between specimen supports was 2 in.

Tile for determining sag in firing were placed in the kiln on refractory knife-edged supports 6 in. on centers. Measurement of sag was made with a depth micrometer and was reported as "sag" in fractional parts of an inch over the original 6-in. span.

The apparatus used in determining translucency consisted of a tinned cylindrical container, 6½ in. in diameter and 7½ in. deep. A Mazda 50-watt frosted bulb was placed in the container in a vertical position, the top of the bulb being 2¼ in. from the top of the container. The light slit in the top of the container measured 0.2 by 0.01 in. Translucency was determined by measuring the maximum thickness of the trial wedge through which the outline of the light slit could be seen. The measurements were made in a photographic darkroom with no lights on.

Color ratings

Bodies 1, 2, and 3	Good commercial whites
" 4 and 5	Fair
" 6, 7, and 8	Poor

[3] A. S. Watts, "Data on Influence of Firing Time on Properties of Some Whiteware Bodies," *Jour. Amer. Ceram. Soc.*, 19 [6] 175–76 (1936).

TABLE IV

PROPERTIES OF BODIES FIRED TO APPROXIMATELY 10 TO 15% OF ABSORPTION

Body	Fired at cone No.	Absorption (%)	Linear shrinkage (%)	Transverse strength (lb./sq. in.)	Impact strength (ft.-lb./sq. in.)	Sag on 6-in. span (in.)	Color*
No. 2	5	10.7	5.8	3300	0.89	0.1	6
L-lithium	9	10.9	5.2	2700	0.91	0.2	8
L-barium	9	10.2	4.7	2600	0.85	0.2	6
L-calcium	14	10.1	5.4	3200	0.89	0.1	2
L-magnesium	15	12.1	4.7	2900	0.86	0.2	2
N-lithium	9	11.1	4.5	2550	0.89	0.2	8
N-barium	5	15.6	3.0	1950	0.79	0.1	1
N-barium	12	8.1	6.0	3650	0.92	0.4	3
N-magnesium	14	12.9	4.0	2450	0.84	0.2	2
H-lithium	10	11.8	2.5	2750	0.85	0.1	8
H-lithium	12	9.8	2.7	3450	0.87	0.1	8
H-barium	9	10.8	3.4	3050	0.91	0.2	1
H-calcium	12	15.8	1.3	2800	0.87	0.1	7
H-magnesium	14	15.3	1.6	2300	0.77	0.1	6
H-magnesium	15	11.5	3.6	2750	0.82	0.4	6

* Color values range from optimum, 1, to poorest, 8.

III. Results

(1) Draw-Trial Runs

The results of the draw-trial runs are given in Figs. 1 to 4. From these data, the final firing temperature and the general behavior of the fluxing agent over a range of temperatures were determined.

(2) Semivitreous Bodies

The properties of the various bodies fired to 10 to 15% of absorption are given in Table IV.

No data were obtained for the N-calcium body owing to the difficulty of obtaining the desired firing temperature by interpolation from the data on draw-trial runs.

The mechanical properties of the L-calcium and N-barium bodies compared favorably with those of body No. 2. The latter bodies, however, were fired at cone 5, whereas the L-calcium and N-barium bodies required cones 14 and 12, respectively, to attain approximately the same absorptions. The L-lithium, H-barium, and N-barium bodies had slightly greater impact strength than body No. 2.

Bodies with high barium content or small amounts of magnesium and calcium frits had an excellent color.

The clay content of the bodies in the L, N, and H series (see Table II) apparently influenced the linear firing shrinkage more than did the type of flux that was used.

(3) Vitreous Bodies

Properties of bodies fired approximately to 1 to 3% of absorption are given in Table V. There are no data for the N-barium, H-lithium, or H-magnesium bodies owing to the difficulty of obtaining the desired firing temperature by extrapolation from the data on draw-trial runs.

The N-calcium body, fired to cone 17, and the N-magnesium, H-barium, and L-calcium bodies had transverse strengths considerably greater than that of body No. 2, but they were lower in impact strength.

A high barium content imparted the best color quality to the body in the vitreous range. The H-barium and N-calcium bodies compared favorably with body No. 2 in translucency.

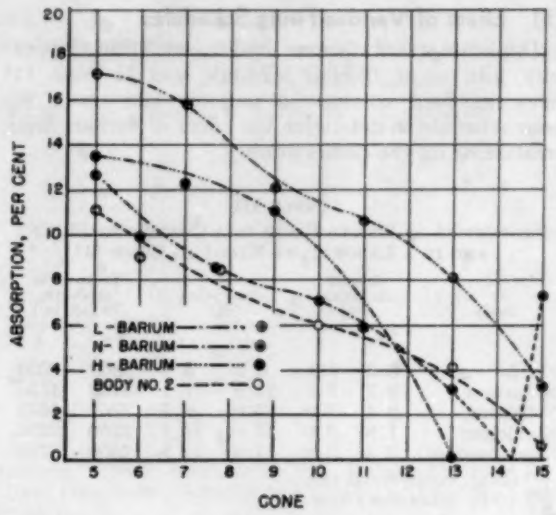


FIG. 1.—Fired absorption of barium bodies drawn at various cones.

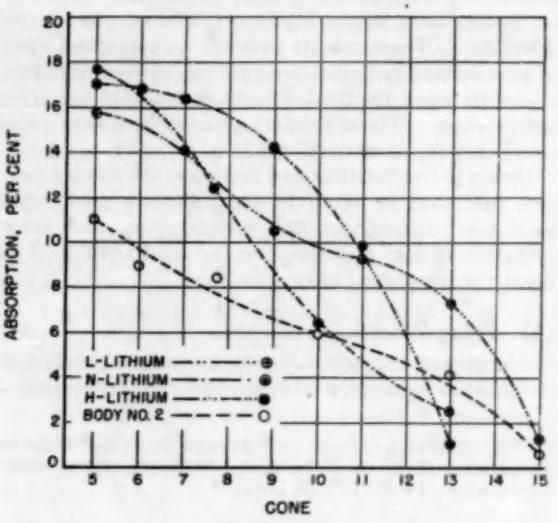


FIG. 2.—Fired absorption of lithium bodies drawn at various cones.

TABLE V

PROPERTIES OF BODIES FIRED APPROXIMATELY TO 1 TO 3% OF ABSORPTION

Body	Fired at cone No.	Absorption (%)	Linear shrinkage (%)	Transverse strength (lb./sq. in.)	Impact strength (ft.-lb./sq. in.)	Sag on 6-in. span (in.)	Color*	Translucency (in.)
No. 2	14	1.1	9.6	4950	0.99	0.8	4	0.13
L-lithium	15	2.5	8.7	5050	0.93	0.4†	8	0.06
L-barium	15	4.0	7.0	3850	0.91	0.4†	5	0.10
L-calcium	17	1.6	8.9	5750	0.95	0.6	4	0.08
L-magnesium	17	4.2	8.6	4700	0.96	0.7	5	0.09
N-lithium	12	1.8	8.6	4600	0.97	0.5	8	0.10
N-calcium	14	4.5	7.2	4450	0.91	0.4	5	
N-calcium	17	0.2	7.4	6050	0.88	0.8	4	0.12
N-magnesium	17	1.5	8.5	6200	0.97	0.8	5	0.10
H-barium	12	0.8	8.1	5450	0.91	0.7	3	0.13‡

* Color values range from optimum, 1, to poorest, 8.
† Bars sagged to base, values probably low.
‡ Translucent at maximum thickness of wedge.

Linear firing shrinkage of all bodies containing eutectic fluxes was lower than that of body No. 2. The shrinkage of the N-calcium body was particularly low at 0.2% of absorption.

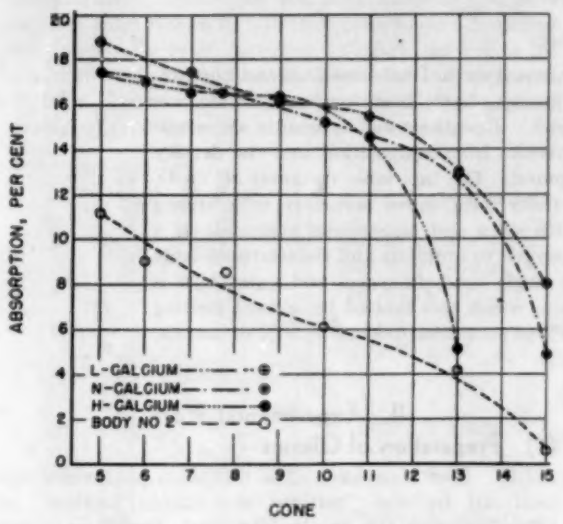


FIG. 3.—Fired absorption of calcium bodies drawn at various cones.

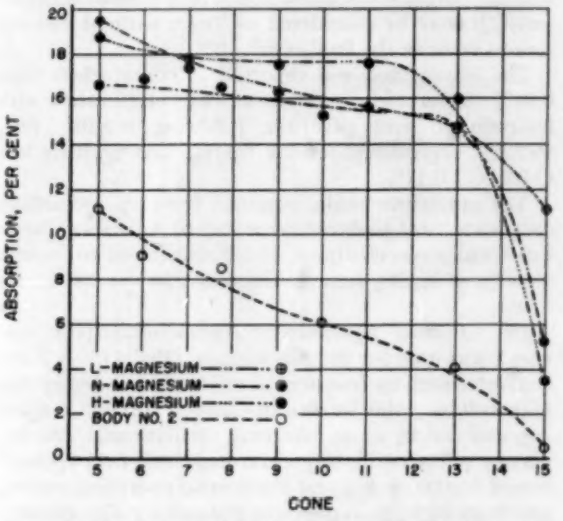


FIG. 4.—Fired absorption of magnesium bodies drawn at various cones.

IV. Discussion

The process of vitrification in a ceramic body is exceedingly complex, and isolation of the effects of a single variable is hardly possible. The data presented, however, indicate that the effect of the addition of a eutectic flux to the body does not exhibit a simple relationship with regard to the amount added or to the melting point of the flux.

Fluxing agents, such as feldspar, which melt incongruently and progressively, take into solution other body constituents, permit greater latitude in firing, and minimize the danger of overfiring and warpage. The rate of firing, of course, is extremely important in this respect.

The eutectic mixtures did not lower appreciably the maturing temperatures of the bodies investigated even though the melting point of the frit itself was comparatively low as in the case of the lithium frit.

V. Conclusions

(1) The eutectic fluxes used in this investigation in general shortened the maturing range of the body considerably.

(2) The eutectic fluxes did not appreciably improve the transverse strength of the body.

(3) The linear firing shrinkage of the fritted bodies in the vitreous range was lower than that of the feldspar body. In the semivitreous range, the effect of the variable clay content influenced the shrinkage more than did the type of flux.

(4) The most promising bodies investigated were those containing barium frit. These bodies had a satisfactory firing range, enhanced color and translucency, and a lower maturing temperature than the feldspar body.

Acknowledgment

This work was done in the ceramic laboratories of Battelle Memorial Institute under an Ohio State University fellowship established by Battelle. The authors acknowledge the permission of Battelle to publish the results and the advice and assistance of John D. Sullivan, supervisor of ceramic research at Battelle Memorial Institute, and of A. S. Watts, Ohio State University, the faculty adviser on the thesis.

BATTELLE MEMORIAL INSTITUTE
COLUMBUS, OHIO

TANTALUM GLASS: K_2O–Ta_2O_5–SiO_2 SERIES*

By Kuan-Han Sun† and Alexander Silverman

Abstract

The partial molal volume and refractivities, based on the Gladstone-Dale and Lorentz-Lorenz formulas of potassia-tantala-silica glasses, have been evaluated from experimental data of density and refractive index. Equations and constants are available for the calculation of volume and refractivities from composition, and the density and refractive index may therefore be computed. The interionic distances of Ta–O, Si–O, and K–O, calculated from the refractivity data, agree favorably with known measured values. Tantala, as compared with silica and phosphorus pentoxide, is a poor "network former." The high ratio of oxygen to tantalum and the relatively large Ta–O distance result in the formation of new singly bonded oxygens and a glass that is loose in structure. The range of composition, which was limited by a fixed melting temperature (1400°C.), extends from 21 to 38% of potassium oxide, 5 to 36% of tantala, and 39 to 71% of silica.

I. Introduction

In the development of new glasses, it is often desirable that the property attributed to a certain component from its position in the Periodic Table be known. A knowledge of refractive index is fundamental to the study and use of glass, and it is normally expected that the higher the atomic weight of a glass constituent used the greater the refractive power. That this qualitative idea is not always true is evidenced by titanium, which has a low atomic weight and a high refractive power in its oxide form. The quantitative relation between the property contribution of a constituent and its position in the Periodic Table can be found only after systematic study in glass melts of the oxide of every element (except inert gases and a few others) in the Periodic Table. The examination of the system, K_2O–Ta_2O_5–SiO_2, therefore is a contribution to such information.

Zachariasen[1] has predicted that tantalum pentoxide alone may form glass, and Morey[2] claims that tantalum oxide will produce a satisfactory glass. Morey, as well as Eberlin,[3] has made tantalum glasses containing oxides of lanthanum, thorium, zirconium, tungsten, titanium, lithium, boron, and silicon, and Finn[4] and his associates have prepared a few soda-lime-silica glasses containing tantalum oxide.

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 2, 1941 (Glass Division). Received October 3, 1940.

Contribution No. 414 from the Department of Chemistry, University of Pittsburgh.

† Submitted to the Graduate School, University of Pittsburgh, in partial fulfillment of requirements for the Ph.D. degree. Acknowledgment is given to the National Tsing-Hua University, China, for granting and extending a fellowship, which made the present study possible, and also to Hurd W. Safford for his cooperation.

[1] W. H. Zachariasen, "Atomic Arrangement in Glass," *Jour. Amer. Chem. Soc.*, **54** [10] 3841–51 (1932); *Ceram. Abs.*, **12** [4] 145 (1933).

[2] G. W. Morey (Eastman Kodak Co.), "Optical Glass," U. S. Pat. 2,150,694, March 14, 1939; *Ceram. Abs.*, **18** [5] 127 (1939).

[3] L. W. Eberlin (Eastman Kodak Co.), "Optical Glass," U. S. Pat. 2,206,081, July 2, 1940; *Ceram. Abs.*, **19** [9] 213 (1940).

II. Experimental Work

(1) Preparation of Glasses

(*A*) *Raw Materials:* The tantalum pentoxide‡ was analyzed by the "tartaric acid-tannin method" of Schoeller[5] and the results obtained, based on a dry sample weight, were Ta_2O_5 96.58%, Cb_2O_5 0.68%, SiO_2 2.01%, TiO_2 0.05%, Fe_2O_3 nil, and ignition loss (1400°C.) 0.62%. Because the amount of Cb_2O_5 present is rather small, it may be considered as Ta_2O_5 without causing serious error in the final result.

The silica§ used was reported to contain less than 0.01% of iron oxide. An analysis by volatilization with hydrofluoric acid gave the following results: SiO_2 99.72%, nonvolatile residue 0.17%, and ignition loss (1400°C.) 0.11%.

The potassium oxide, obtained from c.p. potassium carbonate,‖ was analyzed according to American Chemical Society specifications, and it was found to contain 99.90% of K_2CO_3 (sample dried at 270° to 300°C. for 1 hr.).

(*B*) *Melting Equipment:* An induction-type furnace¶ was used for the glassmelting (Fig. 1). A 3-kw. converter with its transformer charged a condenser to a high voltage; this in turn discharged through a spark gap and coil to set up electrical oscillations. The frequency of the oscillatory electromagnetic field approximated 50,000 cycles, and the normal operating current was from 20 to 25 amperes at 220 volts. The graphite packing and graphite tube were heated by the induced current, and the glass melts in turn, by radiation and convection through the Zircofrax tube, which was located between the graphite tube and the melting cruci-

[4] A. N. Finn, National Bureau of Standards, Washington, D. C., private communication.

‡ Supplied by Fansteel Metallurgical Corp. (lot No. 226).

[5] W. R. Schoeller, Analytical Chemistry of Tantalum and Niobium. Chapman & Hall, Ltd., London, 1937; *Ceram. Abs.*, **17** [9] 317 (1938).

§ Specially prepared and donated by Corning Glass Works.

‖ J. T. Baker Chemical Co. product.

¶ Specially designed by the Ajax Electrothermic Corp.

ble. Some heat was also produced by induction in the platinum container and in the glass melt itself at higher temperatures. Induction furnaces have been rarely used for glass research, but they possess an advantage over resistance-type furnaces in that they can be heated to 1400°C. in less than 45 minutes. The graphite tube, however, burns away slowly and requires occasional replacement.

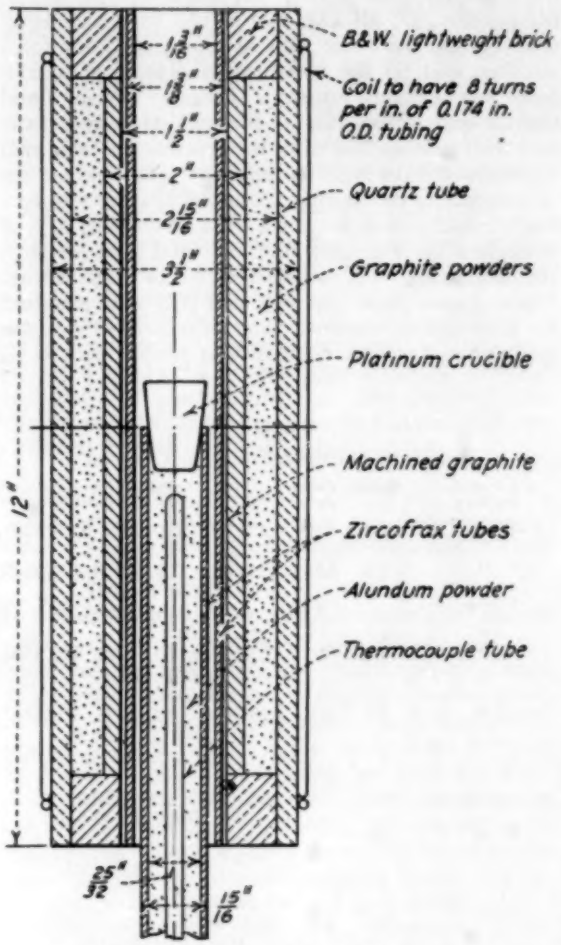


FIG. 1.—Melting furnace; scale 1/2 in. = 1 in.

Temperatures were measured by a Pt-Pt 10% Rh thermocouple and were controlled by a Leeds and Northrup Micromax controller-recorder. The induced current produced in the thermocouple affected temperature readings and was removed by shielding the thermocouple with platinum foil (method of Day and Safford[6]). The controller held the temperature within ±20°C. at 1400°C. The platinum melting crucible, with a capacity of 10 ml., was suspended by a platinum wire attached to a screw control so that the crucible could be raised and lowered easily at the time of "topping." During the melting and "fining" period, the crucible rested on the inner Zircofrax tube. The oven for annealing the glass was the familiar, electrically heated muffle type.

(*C*) *Preliminary Melts:* About 50 initial melts were prepared in order to map the area where good glass could be obtained, and a melting temperature of 1400°C. was maintained for all compositions. The amount of glass produced in each case was 1/2 gm., and the melting time for each batch was 1 hr. As shown in Fig. 2,

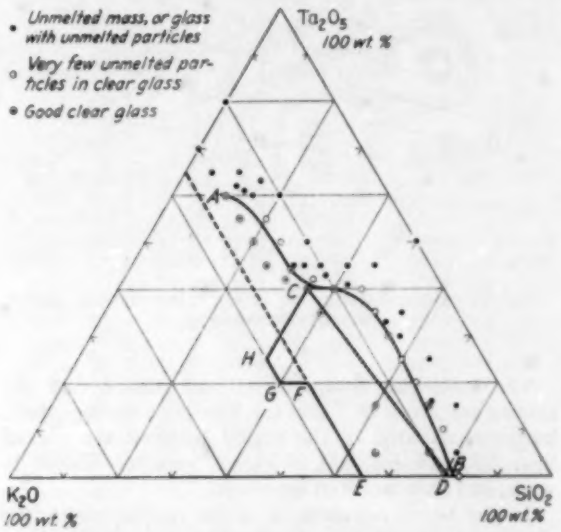


FIG. 2.—Composition of preliminary melts.

the area between the curved line, *AB*, and the 35% K_2O line represents that portion of the system in which good glasses may be prepared at 1400°C.

(*D*) *Final Experimental Melts:* In the *CDEFGH* area (Fig. 2) 33 final experimental melts were prepared and studied. Their compositions, initially based on various molecular ratios, were plotted in weight percentages (Fig. 3). The lines, *T2*, *T3*, *T4*, and *T5*, would meet at the apex representing 100% of Ta_2O_5 if the full-scale triangular diagram were plotted. The molecular compositions of these *T* lines may be represented by $x(1/2Ta_2O_5)\cdot 100SiO_2\cdot mK_2O$, where x is a variable and m is a constant for each *T* line, varying from one line to another. This description applies similarly to all *S* lines and *K* lines in the diagram, with the respective molecular compositions of these lines expressed by $m(1/2Ta_2O_5)\cdot xSiO_2\cdot 40K_2O$ and by $m(1/2Ta_2O_5)\cdot 100SiO_2\cdot xK_2O$. It is convenient to designate any glass by the coordinates of the point representing that glass on the composition diagram; for example, the glass with the weight composition of Ta_2O_5 14.49%, SiO_2 52.55%, and K_2O 32.96% is called "503" in the order of the components *T-S-K* ($Ta_2O_5\cdot SiO_2\cdot K_2O$) because it lies on lines *T5* and *K3*. The numeral, 0, is used for the middle figure because the composition lies on no *S* line. All points were so chosen as to facilitate the

[6] Frank Day, Jr., and H. W. Safford, "Overcoming Thermocouple Errors in High-Temperature Induction Furnaces," *Ind. Eng. Chem.*, **32** [3] 445–46 (1940); *Ceram. Abs.*, **19** [5] 121 (1940).

evaluation of partial molal or partial specific quantities, and each glass belongs to at least two of the three series (i.e., the T, S, or K series).

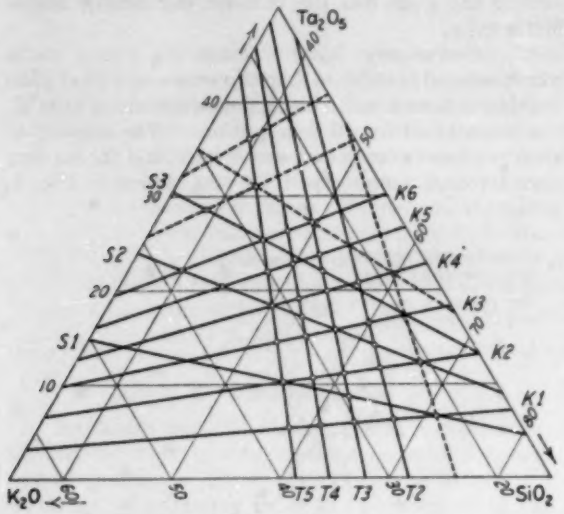


FIG. 3.—Composition of final experimental melts (weight percentages).

The molecular compositions and numbers of the glasses are given in Table I. The glass compositions, however, situated in the region between the curved line, *AB*, and line, *CD*, of Fig. 2, were too viscous to work, and they were not examined.

In the batch calculations of the regular melts, the silica content of tantalum oxide, impurities in the silica, and ignition losses for both have been considered. Corrections for volatilization loss of potassium oxide were made, and the first few melts were used to indicate the magnitude of this correction. The batch was melted in a platinum crucible by "topping" repeatedly at 1320° to 1370°C. The temperature then was raised to 1400°C., and the melt was stirred thoroughly with a platinum rod. This stirring was repeated 4 or 5 times at 15-minute intervals. The melt was allowed to stand for 1 hour to permit the escape of gases, and the temperature was finally raised to 1430°C. for 10 minutes. At the end of this period, the crucible was quickly removed, and the glass was poured on to a flat platinum foil inside a gas-heated glory hole. The glass on the foil was transferred to the annealing oven and cooled naturally from 590°C. to room temperature at a rate not to exceed 2°C. per minute. The total weight of glass in each case was about 20 gm.

(2) Determination of Compositions

Morey and Merwin[7] have successfully used a method to evaluate compositions by weighing both the raw batch and the finished glass to account for the volatilization loss of alkali; they also used platinum crucibles to minimize the corrosion effect on the container.

In the present study, the mechanical loss of material during additions of the batch to the crucible rendered the control of volatilization losses difficult. A partial compensation was introduced by weighing the crude glass 3 minutes after the final batch addition. In applying this correction, it was assumed that (*a*) the batch material lost during "topping" was uniform in composition, (*b*) all CO_2 was driven from the batch after heating the crude glass at top temperature for 3 minutes, and (*c*) the volatilization loss of potassium oxide was negligible after this heating. The silica and tantala were nonvolatile at the melting temperature, and the platinum loss from the crucible for each melt approximated 0.4 mg. Because the volatilization loss of potassium oxide during 2 hours of heating was very low[8] (volatilization loss for a glass containing 30% of potassium oxide is only 0.2% of total glass weight), the correction was considered to be satisfactory. Three glasses (Nos. 025, 420, and 202) were analyzed for their tantala content. The difference between the synthesis and analysis compositions was less than 0.5%.

TABLE I

MOLECULAR COMPOSITIONS OF GLASSES

General formula	Series No.	Value of *m*	Value of *x* (glass No. in parentheses)
$xT \cdot 100S \cdot mK$*	T2	25	2.5(201), 5.0(202), 6.25(220), 7.5(203), 10(204)
"	T3	30	2.5(301), 3.75(310), 5.0(302), 7.5(323), 10(304), 11.25(330), 12.5(305), 15(346)
"	T4	35	2.5(401), 5.0(402), 7.5(403), 8.75(420), 10(404), 12.5(405), 15(406)
"	T5	40	2.5(501), 5.0(512), 7.5(503), 10(524), 12.5(505), 15(536), 20(547), 25(508)
$mT \cdot xS \cdot 40K$*	S1	5	200(111), 400/3(310), 800/7(410), 100(512)
"	S2	10	200(122), 160(220), 400/3(323), 800/7(420), 100(524), 80(025), 200/3(026)
"	S3	15	400/3(330), 800/7(430), 100(536), 75(037)
$mT \cdot 100S \cdot xK$*	K1	2.5	20(111), 25(201), 30(301), 35(401), 40(501)
"	K2	5.0	20(122), 25(201), 30(302), 35(402), 40(512)
"	K3	7.5	25(203), 30(323), 35(403), 40(503)
"	K4	10.0	25(204), 30(304), 35(404), 40(524)
"	K5	12.5	30(305), 35(405), 40(505), 50(025)
"	K6	15.0	30(346), 35(406), 40(536), 60(026)

*T, S, and K represent $\frac{1}{2}Ta_2O_5$, SiO_2, and K_2O, respectively.

[7] G. W. Morey and H. E. Merwin, "Relation Between Composition and Density and Optical Properties of Glass: I, Soda-Lime-Silica Glasses," *Jour. Optical Soc. Amer.*, 22 [11] 632–62 (1932); *Ceram. Abs.*, 12 [6] 218 (1933).

[8] V. Dimbleby, H. W. Howes, W. E. S. Turner, and F. Winks, "Effect on Properties of Soda-Lime-Silica Glass of Continued Remelting in Platinum," *Jour. Soc. Glass Tech.*, 13 [52] 304–21 (1929); *Ceram. Abs.*, 9 [7] 515 (1930).

(3) Measurement of Properties

(*A*) *Density:* Density determinations were made by the displacement principle of Archimedes by weighing samples in air and in toluene. A platinum wire, 0.0098 cm. in diameter and coated with platinum black, was used as the suspension wire to eliminate surface-tension errors. Most of the glasses contained fine gas bubbles, the volumes of which were obtained by microscopic measurements of their diameters, but the total gas content was negligible. The density values obtained were corrected for air buoyancy by equation (1) of Johnston and Adams[9]:

$$d = d' + \frac{0.00118(d' - d'')}{0.00118 + d''}. \qquad (1)$$

d and d'' = true densities of glass and toluene, respectively.

d' = density of glass uncorrected for air bouyancy.

Toluene was selected as the buoyant liquid because some of the glasses containing high percentages of potassia were attacked by water.

(*B*) *Refractive Index:* The refractive indices of the polished glasses with respect to the sodium D line were measured on an Abbé refractometer, using α-bromonaphthalene as contact medium. The observed variations of refractive index in the fourth decimal place were caused by the inhomogeneities in the glasses.

(4) Experimental Data

The measured values of density and refractive index together with glass compositions are presented in Table II.

TABLE II

MEASURED VALUES OF DENSITY, REFRACTIVE INDEX, AND COMPOSITION

Glass No.	Composition (wt. %)* Ta_2O_5	SiO_2	K_2O	d†	v‡	n§
501	5.3	58.6	36.1	2.533	0.3949	1.508
401	5.6	61.0	33.4	2.522	0.3966	1.506
301	5.9	64.0	30.1	2.515	0.3976	1.507
201	6.1	67.4	26.6	2.493	0.4011	1.503
111	6.4	71.2	22.4	2.477	0.4037	1.498
310	8.6	62.2	29.2	2.562	0.3904	1.510
512	10.0	55.5	34.5	2.620	0.3817	1.515
402	10.5	58.3	31.2	2.619	0.3818	1.516
302	10.9	60.6	28.5	2.610	0.3832	1.514
202	11.4	63.6	25.0	2.585	0.3868	1.510
122	12.3	66.7	21.0	2.575	0.3883	1.510
220	13.9	61.9	24.3	2.636	0.3794	1.515
503	14.2	52.9	32.9	2.707	0.3694	1.520
403	15.1	54.8	30.1	2.702	0.3701	1.523
323	15.5	57.9	26.6	2.690	0.3717	1.521
203	16.6	59.8	23.6	2.679	0.3733	1.519
420	17.2	53.5	29.3	2.741	0.3649	1.526
524	18.1	50.5	31.4	2.789	0.3586	1.529
404	19.2	52.2	28.6	2.785	0.3590	1.531
304	20.0	54.4	25.6	2.783	0.3593	1.530
025	20.5	44.7	34.8	2.885	0.3466	1.541
204	20.9	56.8	22.3	2.770	0.3610	1.530
330	22.0	53.0	25.0	2.829	0.3535	1.534
505	22.0	47.9	30.1	2.866	0.3489	1.539
026	22.2	40.3	37.5	2.959	0.3379	1.552
405	22.9	49.8	27.3	2.867	0.3488	1.538
305	23.8	51.8	24.4	2.869	0.3485	1.537
536	25.2	46.1	28.7	2.956	0.3384	1.548
406	26.3	47.6	26.1	2.949	0.3391	1.544
346	27.1	49.7	23.2	2.915	0.3430	1.541
037	28.5	39.2	32.3	3.079	0.3248	1.560
547	30.5	42.9	26.6	3.106	0.3219	1.561
508	35.9	39.6	24.5	3.215	0.3111	1.574

* Percentages were calculated on nonvolatile residue-free basis; this residue, for all glasses, was 0.1% on basis of total weight of glass.
† Density.
‡ Specific volume.
§ Refractive index.

III. Treatment of Data and Discussion of Results

With the small amount of columbium oxide considered as tantalum oxide, the chief impurity in these glasses was 0.1% of the nonvolatile residue introduced with the silica. The system, K_2O–Ta_2O_5–SiO_2, may be considered as one of four components in which the fourth component (nonvolatile residue) is of negligible proportions and remains practically constant. The presence of this small amount of impurity therefore will not materially affect the evaluation of partial quantities because the percentages of potassia, tantala, and silica were calculated on an impurity-free basis.

In the majority of cases, the compositions of the glasses deviated somewhat from the intended values. An extrapolation of observed properties for actual compositions to values for desired compositions was made by assuming the linear addition law to be valid for small composition ranges or for small areas in the triangular composition diagram. This was done graphically on an enlarged triangular diagram to determine the amount of composition change, which was usually very small. The physical properties so shifted were specific volume and specific refractivity, based on the Gladstone-Dale formula[10] rather than on the density and refractive index. The final corrected values for these properties are used in the later treatment.

Sun, Safford, and Silverman[11] have stated that it is such properties as volume and refractivities, based on the Gladstone-Dale and Lorentz-Lorenz[12] formulas, which follow the linear-addition law more closely than do the density and refractive index values, and they have advocated the use of partial quantities for the treatment of property-composition relationships. Accordingly, for all glasses in this study, the molecular volume, V,* and the molecular refractivities, based on the Gladstone-Dale formula, K,† and on the Lorentz-

[9] J. Johnston and L. H. Adams, "Density of Solid Substances with Especial Reference to Permanent Changes Produced by High Pressures," *Jour. Amer. Chem. Soc.*, **34**, 563–84 (1912).

[10] J. H. Gladstone and T. P. Dale, "Researches on Refraction, Dispersion, and Sensitiveness of Liquids," *Phil. Trans. Roy. Soc.* (London), **153** [1] 317–43 (1863).

[11] K.-H. Sun, H. W. Safford, and Alexander Silverman, "Review of Relation of Density and Refractive Index to Composition of Glass," *Jour. Amer. Ceram. Soc.*, **23** [11] 315–26; [12] 343–54 (1940).

[12] (*a*) H. A. Lorentz, "Relation Between Propagation of Light and Density of Matter," *Wied. Ann. Phys. Chem.*, [Series 9], **9** [4] 641–65 (1880).

(*b*) L. Lorenz, "Refraction Constants," *ibid.*, [Series 9], **11** [9] 70–103 (1880).

* $V = M \cdot v$, where M is molecular weight; v, specific volume of glass.

† $K = (n - 1) \cdot V$, where n is refractive index with respect to the sodium D line.

TABLE III

PARTIAL MOLAL AND PARTIAL SPECIFIC QUANTITIES OF TANTALUM OXIDE, SILICA, AND POTASSIUM OXIDE

Series No.	Molecular formula	Partial volume		Partial refractivities			
		$\bar{V}$	$\bar{v}$	$\bar{R}$	$\bar{k}$	$\bar{R}$	$\bar{r}$
			Tantalum oxide				
T2	xT·100S·25K	64.46	0.1459	56.8	0.128	31.31	0.07086
T3	xT·100S·30K	61.23	0.1386	56.6	0.128	30.85	0.06984
T4	xT·100S·35K	59.54	0.1348	56.8	0.128	30.54	0.06913
T5	xT·100S·40K	55.38	0.1253	56.5	0.128	30.00	0.06790
Avg.		60.15	0.1361	56.7	0.128	30.68	0.06943
			Silica				
S1	5T·xS·40K	26.57	0.4423	12.7	0.211	7.488	0.1247
S2	10T·xS·40K	27.19	0.4527	12.7	0.211	7.542	0.1256
S3	15T·xS·40K	27.23	0.4534	12.7	0.211	7.600	0.1266
Avg.		27.00	0.4495	12.7	0.211	7.543	0.1256
			Potassium oxide				
K1	2.5T·100S·xK	33.25	0.3530	18.3	0.195	10.60	0.1126
K2	5.0T·100S·xK	32.55	0.3456	18.2	0.193	10.52	0.1117
K3	7.5T·100S·xK	31.90	0.3387	17.9	0.190	10.40	0.1104
K4	10.0T·100S·xK	31.15	0.3308	17.7	0.188	10.40	0.1104
K5	12.5T·100S·xK	31.50	0.3344	18.1	0.193	10.42	0.1106
K6	15.0T·100S·xK	31.10	0.3302	18.3	0.195	10.38	0.1102
Avg.		31.91	0.3388	18.1	0.193	10.45	0.1110

Lorenz formula, R,* have been calculated. These physical properties, G_T, of the glass series, $x(\frac{1}{2}Ta_2O_5)\cdot 100SiO_2\cdot mK_2O$, which have a definite value of m, were plotted against the number of half moles of Ta_2O_5, x, to permit the evaluation of the partial quantity (property contribution) of tantalum oxide, G_T, where G represents V, K, or R. In this composition formula, m is a constant for each definite series with values of 25, 30, 35, and 40 for the four T series studied. Slopes of these curves, which are approximately linear, represent the partial quantities of $\frac{1}{2}Ta_2O_5$; these values, multiplied by 2, give the property contributions of tantalum oxide. Corresponding partial molal quantities for silica, $\bar{G}_S$, and potassium oxide, $\bar{G}_K$, are evaluated in a similar fashion. The respective property-composition plots were also found to be linear, and the partial quantities so obtained are listed in Table III. Partial specific quantities, $\bar{g}$ (where $\bar{g}$ may be $\bar{v}$, $\bar{k}$, or $\bar{r}$) were obtained by dividing partial molal quantities, $\bar{G}$, by the molecular weight of the constituent under consideration.

For vitreous silica, the values of specific volume and of specific refractivities, based on the Gladstone-Dale and Lorentz-Lorenz formulas, are 0.4542, 0.2081, and 0.1237, respectively, as calculated from the best-known values for density and refractive index.[13] In calculating properties from compositions, many authors have used these figures as constants for silica in glass. The specific volumes and refractivities in Table III indicate that the physical properties of silica in glass and in the vitreous state are not the same and that partial quantities should be used.

The partial specific volume of potassium oxide varies from 0.3302 to 0.3530 as compared to the values of 0.3080 to 0.3589 evaluated by Young and his co-workers[14] for the system soda–potassia–silica. The corresponding specific volume factor of 0.333 was evaluated by Gilard and Dubrul[15] to fit all of the glasses containing less than 30% of K_2O. The molecular refractivity for K_2O ranged from 17.7 to 18.3 and is comparable with the value 19.05 of Biltz, Weibke, and Schrader-Traeger[16] as a factor to fit all glasses.

The specific refractivity of tantalum oxide, 0.128, may be compared with the constants 0.139 and 0.133, respectively, evaluated by Young and Finn[4] for soda-lime-silica-tantala glasses and by Larsen and Berman[17] for crystalline minerals.

According to the method of Lewis and Randall,[18] any extensive property, G, which may be V, K, or R of the system, K_2O–Ta_2O_5–SiO_2, can be calculated from equation (2).

$$G = m_T\cdot\bar{G}_T + m_S\cdot\bar{G}_S + m_X\cdot\bar{G}_K. \qquad (2)$$

m_T, m_S, and m_K = moles of Ta_2O_5, SiO_2, and K_2O.
$\bar{G}_T$, $\bar{G}_S$, and $\bar{G}_K$ = their respective partial molal quantities.

* $R = (n^2 - 1)\cdot V/(n^2 + 2)$.

[13] R. B. Sosman, Properties of Silica. Chemical Catalog Co., Inc., New York, N. Y., 1927; *Ceram. Abs.*, **7** [7] 505 (1928).

[14] J. C. Young, F. W. Glaze, C. A. Faick, and A. N. Finn, "Density of Some Soda-Potash-Silica Glasses as a Function of Composition," *Jour. Research Nat. Bur. Stand.*, **22** [4] 453–64 (1939); *Ceram. Abs.*, **18** [9] 237 (1939).

[15] Pierre Gilard and Léon Dubrul, "Calculation of Physical Properties of Glass: II, Expansion and Density," *Congr. chim. ind.* (Paris), **17** [11] 1013–29 (1937); *Verre & Silicates Ind.*, **9** [3] 25–28 (1938); *Ceram. Abs.*, **18** [4] 95 (1939).

[16] W. Biltz, F. Weibke, and L. Schrader-Traeger, "Molrefraktionen und Molvolumen von Glasern," *Z. anorg. allgem. Chem.*, **234**, 253–88 (1937); condensed article in *Glastech. Ber.*, **16** [4] 131–33 (1938); *Ceram. Abs.*, **17** [10] 326 (1938).

[17] E.S. Larsen and H. Berman, "Microscopic Determination of the Nonopaque Minerals," *U. S. Geol. Surv. Bull.*, No. 848, 2d ed., 254 pp. (1934); *Ceram. Abs.*, **13** [8] 221 (1934); for review see *Ceram. Abs.*, **13** [7] 196 (1934).

[18] G. N. Lewis and M. Randall, Thermodynamics, chapter IV. McGraw-Hill Book Co., New York, N. Y., 1923.

TABLE IV

CALCULATED INTERIONIC DISTANCES

Oxide	R_{oxide}*	R_M†	R_0‡	i_0‡	i_M†	M–O a.u.§	Sources of R_M and i_M
Ta_2O_5	30.68	0.465·	5.95	1.33	0.70	2.03	Kordes
SiO_2	7.543	0.084	3.730	1.20	0.41	1.61	Kordes or Pauling
K_2O	10.45	2.07	6.31	1.34	1.32	2.66	Kordes
K_2O	10.45	2.12	6.21	1.34	1.33	2.67	Pauling

* Experimental. † Known values. ‡ Calculated.
§ M–O represents the interionic distance of the cation, M^{z+} (Ta^{5+}, Si^{4+} K^+) and oxygen ion in a.u. (calculated).

If percentages by weight are used, equation (2) takes the form of equation (3).

$$\bar{g} = p_T \cdot \bar{g}_T + p_S \cdot \bar{g}_S + p_K \cdot \bar{g}_K. \qquad (3)$$

p = weight percentage.
$\bar{g}$ = particular partial specific quantity.

To obtain suitable values of $\bar{G}_T$, $\bar{G}_S$, and $\bar{G}_K$ or $\bar{g}_T$, $\bar{g}_S$, and $\bar{g}_K$ for any unknown glass, the given composition is first changed to the molecular form, $m_T'(1/2 Ta_2O_5) \cdot 100SiO_2 \cdot m_K K_2O$. From the values of m_T' and m_K so obtained, the corresponding partial quantities for potassia and tantala can be interpolated from the values listed in Table III. A conversion of the foregoing molecular formula to $m_T''(1/2 Ta_2O_5) \cdot m_S' SiO_2 \cdot 40K_2O$ obtains a value for m_T'' and interpolation yields the partial quantity for silica. For simplicity and a first approximation, the average values of these partial quantities as listed in Table III may be used in equations (2) and (3). The refractive index may then be computed immediately from the values of volume and of refractivities. A qualitative calculation of this nature indicates that the refractive index of pure tantala glass should approximate 1.9.

Kordes[19] has developed the following simple empirical relation between ionic radius and ionic refractivity:

$$(R/0.603)^{1/3} = c \cdot i \cdot Z^2/(b-1)\,.^* \qquad (4)$$

R = ionic refractivity/Avogadro ion, based on the Lorentz-Lorenz formula.
c = a constant with the value of unity for ions with inert gas configuration and a value of 1.19 for all other ions.
i = ionic radius in a.u.
Z = valence of the ion.
b = the Born repulsion constant.
0.603 = Avogadro number divided by 10^{24} (recently revised).

* The notations have been changed to prevent confusion with those used in this paper. One Avogadro ion contains a number of ions equal to the Avogadro number.

This equation (4) has been shown to be valid for many ions, and it is useful in the calculation of interionic distances for inorganic substances. For compounds in which the cations have smaller radii and higher charges than the anions, Kordes has assumed that the cation was undeformable so that a constant value of ionic refractivity might be assigned to it. The deviation of experimental refractivities from those additively calculated from fixed refractivity values of cation and anion was attributed entirely to the variation in anion refractivity. The ionic refractivity of an anion was thus obtained from the difference between the experimental molecular refractivity of a compound and its cation refractivity. Application of equation (4) permitted Kordes to calculate the anion radius. The ionic radius of the cation was usually small and was assumed to be constant so that the sum of the ionic radii of the anion and cation gave interionic distances. From the values of Pauling and Kordes[19] for the ionic refractivities of tantalum, silicon, and potassium, radii for the oxygen ions in the hypothetical compounds,† Ta_2O_5, SiO_2, and K_2O, have been calculated by the simplified Kordes equation.

$$i_0 = 0.8915\,(R_0)^{1/3}. \qquad (5)$$

i_0 = ionic radius of oxygen in a.u.

R_0, the ionic refractivity of oxygen in the oxide, M_xO_y, was calculated by equation (6).

$$R_0 = (R_{oxide} - x \cdot R_M)/y. \qquad (6)$$

R_M = cationic refractivity.
R_{oxide} = partial molal refractivity of Ta_2O_5, SiO_2, or K_2O (Table III).

The interionic distances, Ta–O, Si–O, and K–O (Table IV), were obtained from the sum of the calculated oxygen radii and from the values of Kordes and Pauling for the ionic radii of tantalum, silicon, and potassium.

An average value of the partial molal refractivity of each oxide was used in the calculations because any variation in this quantity from one glass series to another affected the interionic distance by but a few units in the third decimal. The calculated Si–O distance, 1.61 a.u., agrees fairly well with the experimental value, 1.62 a.u., of Warren,[20] whereas the K–O distances of 2.66 and 2.67 a.u. deviate but little from his value of 2.65 a.u. for potash-silica glass.[21] The corresponding K–O spacing in crystals has been reported as 2.79 a.u.[22] Published values for the Ta–O distance are lacking although, in the X-ray diffraction data of crystalline Ta_2O_5,[23] the strong line with an interplanar

† These compounds maintain a hypothetical existence in glass according to the modern concept of glass structure.

[19] E. Kordes, "Determination of Atomic Distances from Refraction," *Z. physik. Chem.*, **B44** [4] 249–60; [5–6] 327–43 (1939).

[20] B. E. Warren, "X-Ray Diffraction Study of Structure of Glass," *Chem. Revs.*, **26** [2] 237–55 (1940); *Ceram. Abs.*, **19** [8] 187 (1940).

[21] Notes from lecture series by B. E. Warren during summer session, University of Pittsburgh, June, 1940.

[22] Linus Pauling, Nature of the Chemical Bond and Structure of Molecules and Crystals, 429 pp. Cornell Univ. Press, Ithaca, N. Y., 1939; reviewed in *Science News Letter*, **36** [2] 32 (1939); *Ceram. Abs.*, **19** [1] 28 (1940).

[23] J. D. Hanawalt, H. W. Rinn, and L. K. Prevel, "Chemical Analysis by X-Ray Diffraction," *Ind. Eng. Chem. Anal. Ed.*, **10** [9] 456–512 (1938).

spacing of 1.98 a.u. might correspond to this interionic distance.

The excellent agreement between the calculated and experimental values of the K–O distance is surprising in view of the fact that the ionic radii of K^+ and O^{--} are approximately the same.

The structure of tantalum glass is not known, but from a knowledge of the glass-forming behavior of the oxide itself and its periodic relation with phosphorus, tantalum might be expected to be bonded tetrahedrally to 4 oxygens, a condition met by the "glass- or network-formers," SiO_2 and P_2O_5. The Si–O and P–O distances, reported by Warren, are 1.62 and 1.57 a.u., respectively; the corresponding value for Ta–O is 2.03 a.u., as evaluated by the writers.

For a first approximation, the bond strength between two ions may be estimated to be proportional to $Z_A \cdot Z_B \cdot e^2/i_{A-B}$, where Z_A and Z_B are the valences of the 2 ions, A and B; i_{A-B}, the distance between them; and e, the electronic charge.[24] According to this formula, the relative bond strengths of Si–O, P–O, and Ta–O are $-4.94e^2$, $-6.37e^2$, and $-4.93e^2$, respectively. The similarity in the values for Si–O and Ta–O may explain why pure tantala will form a glass. The larger the ratio of the number of oxygens to the number of glass-forming cations, the greater will be the number of singly bonded oxygens in the glass. This condition results in a structure that is loosely bound together. Thus the relatively large ratio of oxygen to tantalum in the system, K_2O–BaO–Ta_2O_5, may explain the fact that no glass could be obtained there. Although P_2O_5 also has a large ratio of oxygen to cation, the bond energy of P–O is much greater than that for Ta–O, and P_2O_5 with BaO will produce a good glass.

The two types of oxygen atoms joined to silicon in the system, K_2O–Ta_2O_5–SiO_2, are (*a*) singly bonded oxygens and (*b*) the oxygens bonded to 2 silicon atoms. If the 4-coordination state for tantalum in the glass is accepted, a third type of oxygen atom will exist, bonded both to silicon and to tantalum. The calculated distance of 1.61 a.u. for Si–O probably is the mean value for these three types of linkage. Similar reasoning will apply when oxygen atoms are bonded to tantalum.

The writers observed that the addition of Ta_2O_5 to a constant SiO_2 and K_2O content resulted in increased coefficient of expansion, fusibility, a tendency to devitrify, and a decrease in viscosity. As Ta_2O_5 was introduced, new singly bonded oxygen atoms were formed with a resultant loosening of the glass structure, causing higher expansion and lower fusibility and viscosity.

The fact that tantalum occupies a position between barium and lead in the Periodic Table might lead to the supposition that its contribution of properties to the glass would lie between corresponding quantities for barium and lead. A comparison of glasses composed of $x(\frac{1}{2}Ta_2O_5)\cdot 100SiO_2\cdot 40K_2O$ (series T5) with the glass compositions, xBaO·100SiO_2·40K_2O and xPbO·100-SiO_2·40K_2O (after Peddle[25]), was made by plotting the density and refractive index values against the values of x. A verification of this supposition is shown in Figs. 4 (*A*) and 4 (*B*). Dispersion measurements were made for the T5 series, and the results indicate that the dispersion and Abbé values of the tantalum glasses also lie between those for barium and lead glasses. The Abbé figures maintained an almost constant value of about 49 in this series.

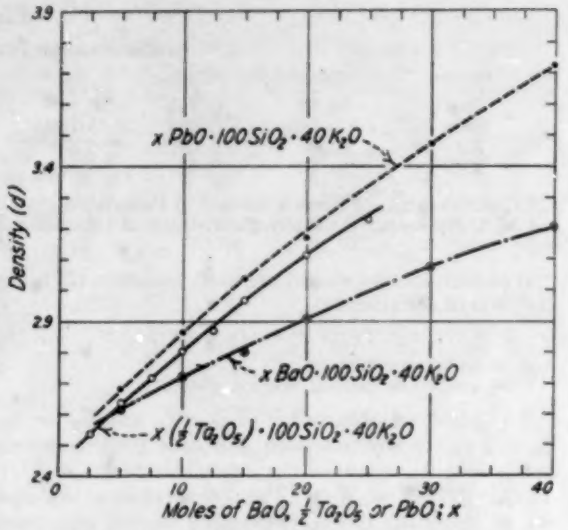


FIG. 4(*A*).—Densities of barium, tantalum, and lead glasses.

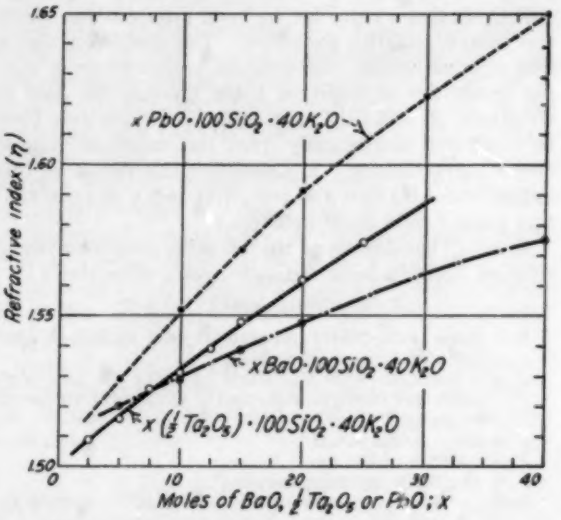


FIG. 4(*B*).—Refractive indices of barium, tantalum, and lead glasses.

[24] F. G. Getman and F. Daniel, Outline of Theoretical Chemistry, 6th ed., p. 614. John Wiley & Sons, Inc., New York, N. Y., 1938; see also footnote 22.

[25] (*a*) C. J. Peddle, "Development of Various Types of Glass: VII, Interaction of Silica, Lead Oxide, and Potassium Oxide," *Jour. Soc. Glass Tech.*, **4**, 310–19 (1920); (*b*) "XIII. Interaction of Silica, Potassium Oxide, and Barium Oxide," *ibid.*, **5**, 212–20 (1921); *Ceram. Abs.*, **1** [6] 165 (1922); for a general review of this series of articles, see *Ceram. Abs.*, **1** [3] 8 (1922).

Some of the glasses containing high percentages of tantala exhibited a yellow coloration. This color was probably caused by a colloidal suspension of platinum derived from the container. Tantalum pentoxide itself is colorless, it is not easily reduced, and in all probability it does not color the glass. In studies on the system potassia–baryta–tantala, the platinum crucibles were severely attacked, and microscopic platinum particles were found in the melt. (Several compositions in this system have been tried, but no glasses could be obtained, probably because tantala is a poor "network-former.") In the system potassia–tantala–silica, one glass with a composition of K_2O 35%, Ta_2O_5 50%, and SiO_2 15% possessed an intense yellow color, and a microscopic examination of the surface disclosed the presence of metallic platinum. There was a further indication that colloidal platinum was the origin of the yellow coloration when a gray color developed after the glass was reheated. Turner and his associates[8] have reported coloration in soda-lime-silica glass when it was remelted in a platinum crucible.

IV. Conclusions

The Lewis and Randall method has been used to evaluate partial quantities for the component oxides in the glass system, K_2O–Ta_2O_5–SiO_2. The fact that these partial quantities do not remain constant with a change in composition from series to series gives further indications of the need for the adoption of the method of partial quantities to express property-composition relationships.

Equations have been developed for the calculation of volume and of refractivities from composition, and therefore density and refractive index may also be computed.

The interionic distances, Si–O and K–O calculated from experimental data by the empirical formula of Kordes, agree favorably with known measured values. The corresponding value for Ta–O has also been evaluated and presented.

Tantala, as compared with silica and phosphorus pentoxide, is a poor "network-former." The high oxygen-to-tantalum ratio and the relatively large Ta–O distance result in the formation of new singly bonded oxygens and a glass that is loose in structure.

Tantala occupies a position between barium oxide and lead oxide in its contribution of properties to glass, and it may be substituted for barium oxide to improve optical properties.

The relatively low melting point of tantala is a desirable factor in its use as a component in glass.

Department of Chemistry
University of Pittsburgh
Pittsburgh, Pennsylvania

USE OF LIQUID SURFACES AS STANDARDS OF SPECULAR GLOSS*

By Dwight G. Moore and Richard S. Hunter

Abstract

It is possible to flow a film of any one of several liquids on the rough ground or sand-blasted face of a black ceramic body and to use the surface of the film as a standard of specular gloss. The specular gloss of the film may be computed from the angle of reflection and the refractive index of the liquid by means of the Fresnel equation. The technique described in this paper was developed for use with the Hunter multipurpose reflectometer to avoid the inaccuracies of specular-gloss measurements which result when the polished black glass surfaces heretofore employed as working standards become abraded in use.

I. Introduction

The polished surfaces of plaques of black glass have been used in the past as working standards of specular gloss[1] (specular reflectance) because of their availability and because it is possible to compute the specular gloss of each plaque from its refractive index. Specular gloss is usually expressed as the fraction of incident light specularly reflected by a surface under specified angular conditions of illumination and viewing.[2]

Specular reflection occurs at the surface of an object, and any change in the physical character of the surface will affect its specular gloss. Thus the scratching of a black glass plate resulting from its day-to-day use has been found to reduce its specular gloss significantly over a period of time. An investigation is being conducted at the National Bureau of Standards wherein the slow changes in specular gloss of a number of porcelain enamel panels exposed out-of-doors for a term of years are being measured with the multipurpose re-

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 3, 1941 (Enamel Division). Received January 13, 1941.

[1] R. S. Hunter and D. B. Judd, "Development of Method of Classifying Paints According to Gloss," *A.S.T.M. Bull.*, No. 97, p. 11 (March, 1939).

[2] R. S. Hunter, "Methods of Determining Gloss," *Jour. Research Nat. Bur. Standards*, **18** [1] 19–39 (1937); R.P. 958; *Ceram. Abs.*, **16** [4] 107 (1937).

flectometer.[3] A readily available, suitably reproducible standard of specular gloss is therefore needed for the tests.

The liquid films described herein were found to meet this need and also the need for reproducible standards for measurements of the specular gloss of paints, plastics, papers, and various ceramic products. These measurements are used to test the materials both for initial specular gloss, for instance, as required in the A.S.T.M. Tentative Method of Test for Specular Gloss of Paint Finishes,[4] and for loss of specular gloss due to weathering, abrasion, and chemical attack. Measurements of loss of specular gloss are required in the standard tests of the Porcelain Enamel Institute.[5]

The refractive indices of the several liquids available for use as standards may be found in a number of handbooks, and the specular gloss as a function of refractive index is given by the Fresnel equation. The refractive index of black glass varies from piece to piece, however, and a new unscratched piece must therefore be measured with a suitable refractometer before a value can be assigned to it.

II. Fresnel Equation for Specular Gloss

According to the Fresnel theory,[6] the specular gloss, G_s, or specular reflectance of an optically smooth surface of a body in contact with air, is as follows:

$$G_s = \frac{1}{2}\left[\frac{\sin^2(i-r)}{\sin^2(i+r)} + \frac{\tan^2(i-r)}{\tan^2(i+r)}\right],$$

Where

i = angle of incidence.
r = angle of refraction so that $n \sin r = \sin i$.
n = refractive index of body.

In Fig. 1, specular reflectance is plotted according to the Fresnel relation as a function of refractive index for three angles of incidence, namely, 45°, 60°, and 75°. From this figure, the specular gloss of the surface of a liquid of known refractive index at any one of these angles can easily be found.[7]

The three angles chosen are those most important in specular-gloss measurements. The first, 45°, has been widely used for all types of materials such as ceramic ware, textiles, papers, and paints. An angle of 60° has been suggested more recently as the angle for measurements made to classify paints according to gloss,[1] and 75° has been suggested as the angle for measuring the gloss of papers and paper products[8] as well as the sheen of painted surfaces.

III. Liquid Films for Standards of Specular Gloss

A cup-shaped depression, into which was poured any one of a number of suitable liquids, was used by Hunter[4(b)] as a standard of specular gloss. Such a standard, however, could not be used with the multipurpose reflectometer because the test surface faces downward when it is exposed in the instrument. It was found, however, that the film of liquid which adheres to the underside of a plate because of molecular attraction may possess a surface suitable for a standard of specular gloss.

To make a satisfactory gloss standard, a liquid film must be optically smooth and clean, and there must be an insignificant amount of reflection from elements below the surface. Liquids at rest normally possess surfaces which are optically smooth; the first requirement consequently is not difficult to meet. To insure that the film is clean, the backing to which the liquid is applied must be of material which is not dissolved by the liquid and which is carefully washed beforehand. To insure that all reflection is from the front surface, a clear liquid is used on a black plate which has a mat finish.

The procedure used to obtain suitable films is as follows: The surface of a flat piece, either of black glass or of black porcelain enamel that is free from waviness, is roughened by light sandblasting or by rough grinding on a lap. It is cleaned by washing with soap and water and rinsed first with warm water and then with alcohol. After it is dried, the piece is wetted with the desired liquid by pouring a small quantity on the area to be used and by tilting the specimen to spread the liquid. The excess is drained off by holding the plate in a vertical position for a few seconds. The surface is quickly placed over the gloss-sample opening of the multipurpose reflectometer[3] used for the specular-gloss measurements, and a setting is made in the usual manner.

Moderately volatile liquids are convenient to use with this technique because the plates and the instrument parts which may become wetted are easily cleaned after use. The settings on volatile liquids, of course, must be made rapidly because the films may last only for a few seconds. Carbon tetrachloride and carbon disulfide furnished films which evaporated too rapidly for accurate settings. Benzene could be measured, but only a few seconds were available for the setting. Distilled water, 95% ethyl alcohol, petrolatum, and α-chlornaphthalene gave satisfactory films. The latter two, however, have a low volatility which necessitates careful cleaning of the instrument parts around the gloss opening after their use.

[3] R. S. Hunter, "Multipurpose Photoelectric Reflectometer," *Jour. Research Nat. Bur. Standards*, **25** [5] 581–618 (1940); R.P. 1345.

[4] "Tentative Method of Test for Specular Gloss of Paint Finishes." Book of A.S.T.M. Tentative Standards (1939).

[5] Porcelain Enamel Institute, (*a*) "Standard Test for Acid Resistance of Porcelain Enamels" (1937); (*b*) "Standard Test for Resistance of Porcelain Enamels to Surface Abrasion" (1938).

[6] (*a*) A. Fresnel, "Calcul des teintes que polarisation développe dans lames cristallisées," *Ann. chim. phys.*, **17**, 194, 312 (1821).

(*b*) R. S. Hunter, "The Glossmeter," *Nat. Paint, Varnish, and Lacquer Assn., Sci. Sec. Circ.*, No. 456 (1934).

[7] Moon has recently published a table of Fresnel reflections (see Parry Moon, "Table of Fresnel Reflection," *Jour. Math. Phys.*, **19**, 1–11 (1940)). This table, however, is not ideally suited for finding specular gloss because the large interval of refractive index (0.1) and the use of radians to express the angle (i) make the interpolation, which is necessary to its use for this purpose, inconvenient.

[8] Institute of Paper Chemistry, "Instrumentation Studies: VI, Modified Oxford Glarimeter," *Paper Trade Jour.*, **104**, TS 16 (1937).

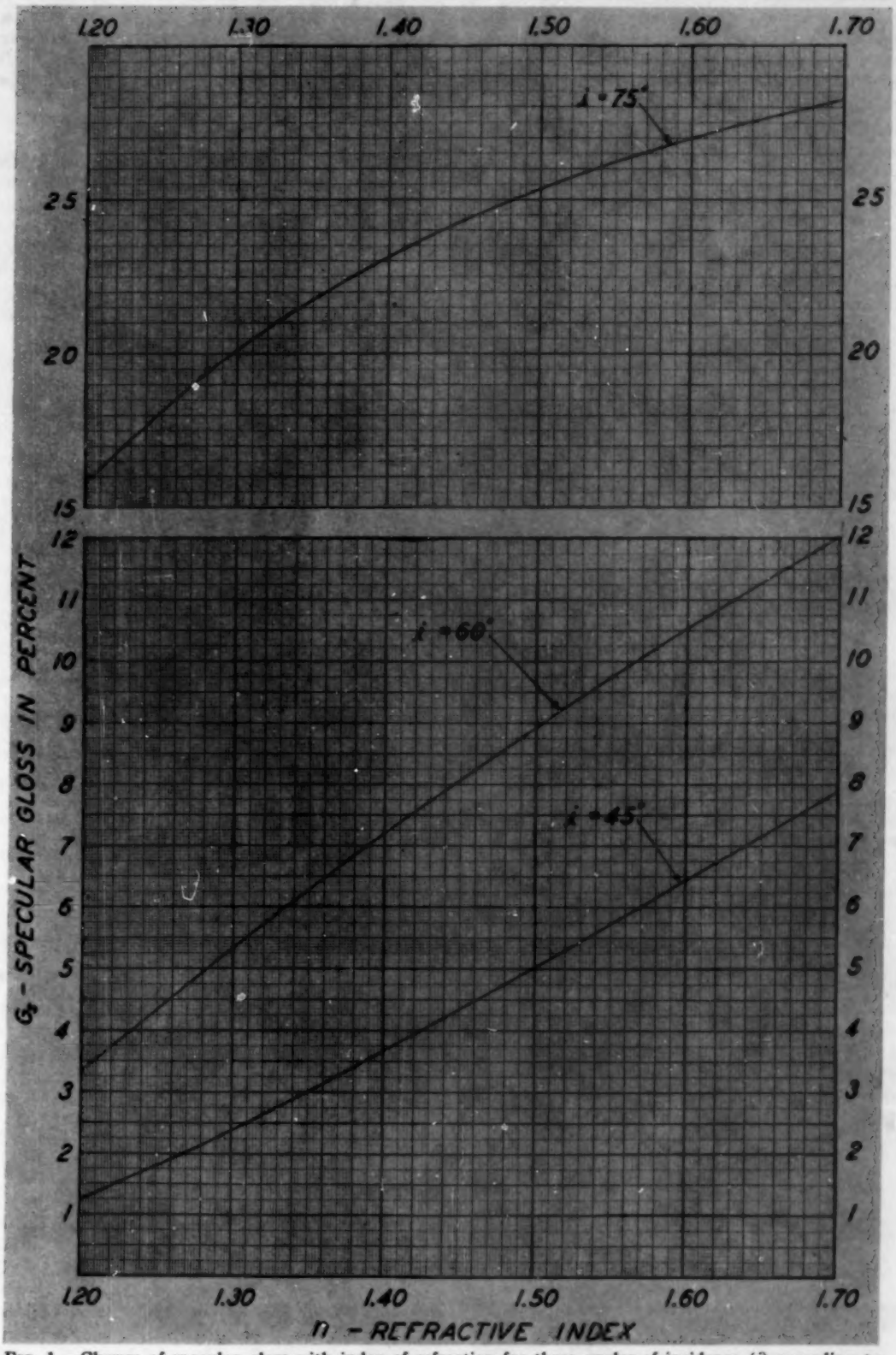


FIG. 1.—Change of specular gloss with index of refraction for three angles of incidence (i) according to the Fresnel equation.

Monochlorbenzene seemed to be especially well suited as a specular-gloss standard. Its specular reflectance is in the same range as the porcelain enamel and other glossy finishes commonly met in practice, it is readily available in the required purity, and its film remains intact for about 30 seconds.

Because of evaporation, the surfaces of monochlorbenzene and other volatile liquids fall below the temperature of air in which they are exposed. Change of temperature alters the refractive index of any liquid, as indicated for monochlorbenzene in Table I and therefore should change the specular gloss of its surface. In the present study, however, one nonvolatile liquid (petrolatum) and water, which is relatively nonvolatile and which has an unusually low temperature coefficient of refractive index, were compared for specular gloss with more volatile liquids. No change of specular gloss from surface evaporation was evident, and accordingly it is assumed in this study that the surface temperature of each liquid film was effectively that of the surrounding air.

TABLE I

CHANGE IN REFRACTIVE INDEX AND SPECULAR GLOSS OF MONOCHLORBENZENE WITH TEMPERATURE

(1) Temp. (°C.); (2) refractive index (n_D); (3) specular gloss as calculated from Fresnel relation (%)

(1)	(2)	(3)
15	1.527	5.40
20	1.525	5.37
25	1.523	5.34
30	1.520	5.30
35	1.518	5.27

Monochlorbenzene and several other of the volatile liquids unfortunately tend to dissolve the baked enamel finishes frequently used on gloss-measuring instruments. It was found in the present study, however, that the soluble finish could be protected by brushing several layers of black india ink over the areas likely to be wetted.

IV. Experimental Intercomparison of Specular-Gloss Values of Several Liquids

Specular-gloss settings at 45° were made with a multipurpose reflectometer on the films of a number of liquids and on two pieces of polished black glass. A film of monochlorbenzene was used as the working standard, and values were obtained for the other surfaces relative to it. These determinations are shown in Table II, together with the specular-gloss values computed from the refractive indices of the materials.

The agreement with calculated specular gloss for the first black glass plate, which had a good optical polish, is as good as that for the liquids. The second plate, which had numerous small, almost microscopic scratches on its surface from normal use, gave a specular gloss of about 0.97 of its calculated value. A specular-gloss error of 3% would therefore result from its use as a standard.

V. Conclusion

The good agreement obtained between experimental values and those computed from the Fresnel equation indicates that a number of liquids give surfaces suitable for standards of specular gloss. Within the range of specular gloss from 2.78 to 6.89% covered by the present study, there was no discrepancy greater than ±0.04, as shown in Table II. Slight scratching of a black glass surface, however, may reduce its specular gloss by more than three times this amount. The writers therefore recommend that black glass surfaces which have suffered any observable abrasion be used only as working standards and that they be calibrated as often as necessary against the surfaces of liquids prepared according to the new technique.

TABLE II

MEASURED AND CALCULATED VALUES OF 45° SPECULAR GLOSS OF SURFACES OF SEVERAL LIQUIDS AND TWO DIFFERENT PIECES OF PLATE GLASS

Liquid	Index of refraction at 26°C. (n_D)	G_s, specular gloss (%): From Fresnel equation	G_s, specular gloss (%): By measurement*
Monochlorbenzene	1.523	5.34	5.34†
Distilled water	1.332	2.78	2.74
Ethyl alcohol	1.364	3.19	3.22
Benzene	1.497	4.98	5.02
α-chlornaphthalene	1.632	6.89	6.92
Petrolatum, USP	1.467	4.57	4.57
Black glass A (new)	1.539	5.56	5.54
Black glass B (slightly scratched)	1.522	5.32	5.18

* Measurements made with multipurpose reflectometer having corrected gloss scale.

† Instrument adjusted to read 5.34 with monochlorbenzene.

It is also suggested that the central region of the scale of a glossmeter may be calibrated by means of a series of liquids such as those listed in Table II. Corrections for the extreme as well as the intermediate points of the scale may be obtained by a method previously outlined by Hunter,[3] and a correction curve, if needed, may be constructed from the two groups of data.

NATIONAL BUREAU OF STANDARDS
WASHINGTON, D. C.

STUDY OF THE EFFECT OF SOLUBLE SALTS PRESENT IN ENAMEL MILL LIQUORS*

By T. L. Hurst and A. I. Andrews

Abstract

Studies were made of the solution of the frit during milling, the soluble salts derived from the frit were identified and studied, and some properties of the slips and mill liquors were investigated. The influence of some soluble salts present in cover-coat enamels on enamel film strength is shown, and a theory regarding the mechanism of tearing has been developed. The function of some salts, particularly sodium hydroxide and sodium nitrite, in eliminating tearing was studied, and the manner in which these salts improve film strength is reported.

I. Introduction

(1) Purpose of the Study

The object of this investigation was to determine the factors responsible for the tearing of enamels and the mechanism by which good film strength may be developed.

Enamel film strength is defined in this study as that property of an enamel coating which permits it to resist disruption during the operations of drying and firing.

The problem was investigated from the viewpoint of (1) the solution of the frit, (2) the selective crystallization of the materials dissolved from the frit, and (3) the use of electrolytes and their effect on the film strength of enamels. This last point also involved physical-chemical studies of the systems of salts independent of the frit glass. The effect of such systems on the enamel films at temperatures below the fusion of the frit was considered to be very important.

(2) Survey of the Literature

Several writers[1] have reported the effect of the ratio of Na_2O to B_2O_3 on the consistency and working properties of enamel slips. Cook[1(b)] and others[1(c) to (f)] have reported that the presence of borax in the slip accompanies such surface defects as tearing and crawling. Cooke[1(c)] identified crystals of sodium borate, sodium carbonate, sodium fluoride, and sodium sulfate in the dried enamels and reported that borax aggravates tearing. References to the various effects of certain salts on the set of enamel slips and on the metal base are frequent and are in good agreement with each other. Rosenberg[2] found that surface hardening and brushing difficulties are aggravated by high quantities of borax and boric acid in the slip. He attributes tearing to the shrinkage of borax during melting and to the surface tension of the molten material.

Theories have been advanced recently to explain the widespread and rather successful use of special electrolytes, such as sodium nitrite, to correct tearing and improve film strength. Both Lange[3] and Rosenberg have reported that tearing is reduced by sodium nitrite because this salt melts at low temperature, wets the enamel, and bonds it together until the film is completely fused. Rosenberg claimed that the function is purely mechanical. Hartshorn[4] proposed a closer control of the ratio of Na_2O to B_2O_3 in enamel slips by removing part of the mill liquor and replacing it with solutions of known concentrations of sodium nitrite and soda ash. He found that additions of sodium nitrite correct tearing in enamels in which the original ratios of sodium oxide to boric oxide vary widely. Howe[5] believed that slow drying by conduction rather than by convection reduces tearing.

II. Procedure

Six typical sheet-steel cover-coat frits were selected for study. Two of these were ordinary opaque, three were superopaque, and one was acid resistant. The frits were milled with distilled water only under

* Presented at the Forty-Second Annual Meeting, The American Ceramic Society, Toronto, Canada, April 11, 1940 (Enamel Division). Received June 20, 1940.

This paper is based on a thesis submitted by the senior author as partial fulfillment of the requirements of the degree of Doctor of Philosophy in Engineering, and is published with the permission of the Graduate School of the University of Illinois. This work was done on a fellowship sponsored by the Ferro Enamel Corporation, Cleveland, Ohio.

[1] (*a*) G. H. McIntyre and R. E. Bevis, "Frit Solubility: I, Comparison of Methods of Determination and Relation of Soluble Salts to Enamel-Slip Consistency," *Jour. Amer. Ceram. Soc.*, **19** [9] 249–52 (1936); "II, Controlled Variables of Frit Composition and Their Relation to Enamel Consistency," *ibid.*, **21** [5] 184–88 (1938).

(*b*) H. L. Cook, "Note on Solubility of Enamel Frit in Mill Water," *ibid.*, **10** [5] 339–43 (1927); "Observations on Effect of Various Electrolytes Added to Enamel Suspensions Made With and Without Clay," *ibid.*, **10** [5] 344–46 (1927).

(*c*) R. D. Cooke, "Study of Soluble Salts in Enamels," *ibid.*, **13** [9] 658–61 (1930).

(*d*) R. R. Danielson, "Effect of Soluble Salts on Properties of Enamels," *ibid.*, **12** [8] 538–47 (1929).

(*e*) R. J. Whitesell, "Effect of Soluble Salts Formed During Aging on Scumming of Enamels," *ibid.*, **20** [3] 72–75 (1937).

(*f*) A. I. Andrews, Enamels, Twin City Printing Co., Champaign, Ill., 1935; 410 pp.; *Ceram. Abs.*, **14** [7] 158 (1935).

[2] J. E. Rosenberg and A. F. Langerman, "Tearing of Vitreous Enamels," *Jour. Amer. Ceram. Soc.*, **23** [3] 80–86 (1940).

[3] L. A. Lange, "Effect of Sodium Nitrite in Cover Enamels," *Bull. Amer. Ceram. Soc.*, **18** [10] 360–65 (1939).

[4] T. D. Hartshorn, "Control Mill Liquor to Eliminate Tearing," *Ceram. Ind.*, **34** [2] 50 (1940); *Ceram. Abs.*, **19** [4] 87 (1940).

[5] E. E. Howe, "Influence of Drying Methods on Tearing," *Better Enameling*, **10** [12] 13–15 (1939); *Ceram. Abs.*, **19** [8] 183 (1940).

definite conditions of time and temperature to varying degrees of fineness. Duplicate fineness tests were made and checked to within 0.5-gm. residue on a No. 200 sieve from a 50-cc. sample of slip. The mill liquors were filtered from the slips, and portions of each were evaporated. The residues, which represented the products of the solution of the frit, were analyzed petrographically, spectroscopically, and by X rays. Determinations of the specific gravity, the weight residue per gram of liquor, and the pH value were also made on all of the liquors.

The exchangeable ions introduced into the slips during milling were identified by passing the mill liquors through prepared clay and permutite, removing the exchanged ions by standard methods, and analyzing the extract spectroscopically. The effect of several salts on the behavior of enamel slips was investigated by base exchange and pH studies. The usual procedures for these determinations were followed, and observations were made chiefly on the reactions produced by the additions of solutions of sodium fluoride, sodium chloride, sodium metaborate, and sodium phosphate to clay suspensions.

Ground frits were dried, and the particle size, shape, and size distribution were determined for the portions which were collected between sieves Nos. 200 and 325. Microscopic observations and projection methods described by Berger,[6] Tooley,[7] and others were employed for this study.

The effect of single electrolytes on the properties of enamels was investigated by dry grinding the frit and by adding clay, distilled water, and electrolyte premixed in the proper proportions. Enamels sprayed at 40 gm. per sq. ft. and fired from 600° to 1500°F. in intervals of 100° were examined for surface properties and film strength.

The relationship between sodium oxide and boric oxide in the fused enamel was studied by preparing enamels in the same manner, the only variable being the electrolyte additions. The total amount of electrolyte was maintained at 1 lb. of total sodium oxide plus boric oxide per 100 lb. of frit, and the ratio of Na_2O to B_2O_3 was varied through a range from 0.0656 to 2.220. Boric oxide was always added as boric acid, whereas sodium oxide was introduced first by sodium nitrite and sodium hydroxide and later by many other sodium salts.

These enamels were sprayed at 40 gm. per sq. ft., dried, and fired from 1000° to 1500°F. in 100° intervals. Observations were made of the drying behavior (especially the selective crystallization of the electrolytes), the firing behavior, and the film strength of the fired enamels.

Guided by the results of the foregoing studies, various other salts were added to enamels which were prepared in the same manner. These salts were selected in such proportions as to give eutectic compositions, or high melting combinations, and to provide ions other than sodium. These electrolytes were added in equimolecular ratios with boric acid and in amounts sufficient to provide 1 lb. of total oxide equivalent per 100 lb. of frit. The enamels were sprayed, dried, and fired, and the drying behavior, brushing quality, and tearing resistance were observed.

III. Results and Discussion

(1) Solution of the Frit

Analyses of mill liquors showed that increased fineness of grinding increased the total solution of the frit and that with continued grinding the pH values of the liquors approached a condition of equilibrium. The solution of the frit is a leaching process rather than a true uniform solution.

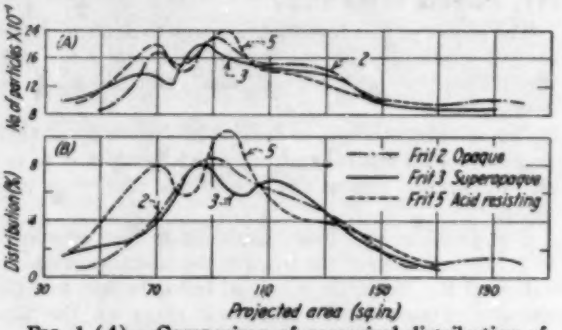


FIG. 1 (*A*).—Comparison of numerical distribution of particles of frits 2, 3, and 5 in the most stable configuration; (*B*) comparison of the percentage distribution of particles of frits 2, 3, and 5 in the most stable configuration.

As shown in Figs. 1 (*A*) and (*B*), the shape, size, and size distribution of the frit particles were similar regardless of the composition. Although increased fineness of grinding increased the total amount of soluble material introduced into the slip from the frit, there was no definite correlation between the frit particles themselves and the film strength, except that coarse particles were generally more resistant to tearing than finer ones.

The residues of dried mill liquors consisted chiefly of sodium fluoride, borax, sodium metaborate, sodium metasilicate, sodium carbonate, sodium sulfate, and a gel of silica with a trace of alumina.

(2) Properties of the Slip

The total amount of salts in solution is an important factor. The slips were so highly buffered that, even in the absence of mill-added electrolytes, changes in total alkalinity did not change their pH values. The pH values therefore failed to serve as criteria for slip properties and film strength. This observation was confirmed by Carter,[8] who found that under plant conditions observed for more than three months the total alkalinity varied considerably whereas the pH remained constant.

[6] Edwin Berger, "Crushing and Sieving of Glass to Insure Control of Surface of Grains," *Jour. Soc. Glass Tech.*, **20** [81] 384–404 (1936); *Ceram. Abs.*, **17** [1] 11 (1938).

[7] F. V. Tooley and C. W. Parmelee, "Powder Method for Measurement of Chemical Durability of Glass," *Jour. Amer. Ceram. Soc.*, **23** [10] 304–14 (1940).

[8] H. D. Carter, "Control of Gray Enamel Manufacture," *Proc. Porcelain Enamel Inst. Forum, Third Forum, Oct., 1938*, pp. 117–33; *Ceram. Abs.*, **18** [6] 148 (1939).

In the absence of mill-added electrolytes, the most abundant cations in the enamel mill liquors were sodium, potassium, and calcium.

The action of sodium phosphates in facilitating milling is made possible by the adsorption of the anion by the clay. The base-exchange capacity of the clay is considerably increased by this reaction, thereby increasing the deflocculation of the system and speeding the milling action.

There are also indications that soluble fluorides, sulfates, and possibly nitrites enter into anion exchange, but they do not increase the deflocculation of the clay.

All of these reactions were more effective with kaolinite than with the montmorillonite type of clays, which confirms the observations of Murphy.[9]

(3) Effect of Certain Soluble Salts

Enamels that contained metal organic and colored inorganic salts were fired at 1000°, 1100°, and 1200°F. The carbon residues and the colors produced by these additions showed that most salts precipitated principally on the surface of the films. The undersides of these enamels were white, but the surfaces were definitely colored. The color gradients between the top and the under surfaces were absent except that cobalt salts caused a slight diffusion of color observed when the enamel was fired to 1500°F.

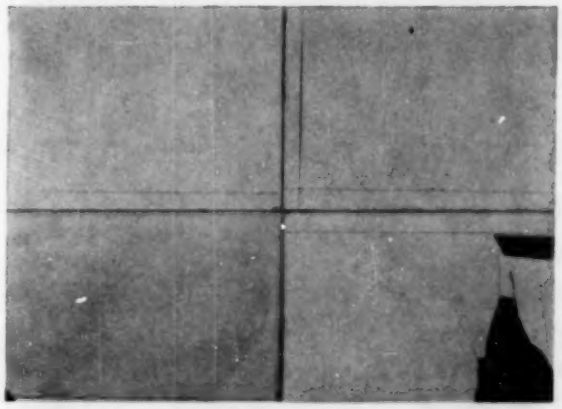


FIG. 2.—Typical enamel films showing the precipitation of soluble salts at the surface on drying.

Shorelining was found to be definitely associated with the rhythmic precipitation of the soluble salts at the surface during drying (Fig. 2). Shorelining and surface scumming developed when sodium sulfate alone was present, whereas additions of sodium nitrite to the mixture reduced shorelining and improved the surface gloss.

Each electrolyte had a definite and characteristic effect on the enamel film; for example, films containing only boric acid were extremely hard and brittle and those with magnesium carbonate or sodium fluoride were soft and powdery.

[9] H. F. Murphy, *Hilgardia*, 12 [5] (February, 1939).

Observations of the progress of the development of the enamel revealed that fusion took place from the top outer surface inward and not from the metal side outward, regardless of the soluble salts that were present.

Tearing always resulted when boric acid was added to enamels, whereas the proper additions of sodium hydroxide, sodium nitrite, and some of the other salts with boric acid eliminated this trouble. Figure 3 illustrates the characteristic curling and tearing in a film that contained only boric acid fired to 1200°F.; the absence of such defects when sodium nitrite alone was present is also shown.

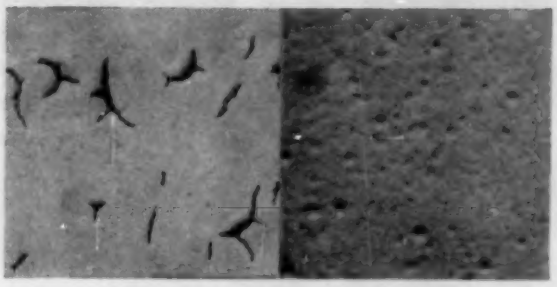


FIG. 3.—(*Left*) Characteristic curling and tearing of enamels which contain high boric acid; (*right*) enamel film which contains only sodium nitrite shows no tearing. The bumps visible in both films are caused by ground-coat reboil and indicate that reboil does not cause tearing but may aggravate it; approximately ×2.5.

Salts, other than sodium nitrite and sodium hydroxide, were used with fair success to correct tearing. Tearing was eliminated, but other defects, such as blistering, scumming, and pitting, were usually encountered and were caused chiefly by the failure to eliminate the anions of the salts before the fusion of the enamel.

(4) Properties of Salts and Salt Mixtures

The solubility of boric acid is relatively low, and the seeding effect of the first crystal in concentrated solutions is important.[10] Boric acid crystallizes in concentrated, interlaced sheaves and plates. These crystals contain water of crystallization which is evolved in a stepwise manner over a considerable range of temperature. This dehydration causes the material to seethe and to expand to many times the original volume. Figure 4 shows 1-gm. samples of boric acid that were dehydrated by direct heating in one case and were dissolved in water and dehydrated in the other. This treatment was halted approximately at the point of greatest expansion, which was just before the material melted. In the expanded condition, the mass possesses remarkably strong, tough skins or films. After melting at approximately 561°F., the residue subsides to a small volume. Melted boric acid has a high surface tension, and it is very viscous at its melting temperature. With rising temperatures, the viscosity decreases more rapidly than does the surface tension.

[10] D. Vorlander and I. Ernst, *Z. physik. Chem.*, 93, 521–26 (1919).

Sodium salts, especially sodium hydroxide and sodium nitrite, are very soluble in water. Crystals of these salts, which melt sharply at 605° and 519.8°F., respectively, do not expand or seethe on heating. The melted salts have low surface tensions and viscosities, and they are therefore extremely mobile.

FIG. 4.—Dehydration expansion or swelling of boric acid crystals; (*top*) boric acid crystals (1 gm.); (*right*) dried solution of boric acid (1 gm. solid); (*left*) boric acid crystals dehydrated by direct heating (beakers, 80 mm. in diameter).

By means of Raman spectra, Hibben[11] demonstrated that when sodium hydroxide is added to boric acid solutions, a product which ionizes as sodium metaborate is formed until one mole of base is added for each mole of acid. Further additions of base cause no change in the ionization of the system. According to Hibben, when a molecular ratio of 1 to 2 exists, the following reaction is indicated where the $NaBO_2$ is completely ionized:

$$2NaOH + 4H_3BO_3 = Na_2B_4O_7 + 7H_2O$$
$$Na_2B_4O_7 = 2NaBO_2 + 2B(OH)_3.$$

With equimolecular proportions, the reaction proceeds as

$$NaOH + H_3BO_3 = NaBO_2 + 2H_2O.$$

The presence, however, of a stable acid, such as HCl, drives the reaction toward the left, increasing the relative concentration of boric acid.

Sodium metaborate, the simplest sodium borate compound, is more soluble than either boric acid or sodium tetraborate. It may be made by dry fusion of its constitutents or by crystallization from solution. In either case, it crystallizes readily, and melts containing it are extremely difficult to cool to a clear glass.[12(a)] It also contains water of crystallization which is released on heating. Its melting point of 1770°F. is the highest in the system Na_2O–B_2O_3. Its surface tension has not been reported at temperatures below 1859°F.[12]

[11] J. H. Hibben, *Amer. Jour. Sci.*, **35A**, 113–25 (1938).

[12] (*a*) G. W. Morey and H. E. Merwin, "Phase Equilibrium Relationships in the Binary System Sodium Oxide–Boric Oxide, With Some Measurements of the Optical Properties of the Glasses," *Jour. Amer. Chem. Soc.*, **58** [11] 2248–54 (1936); *Ceram. Abs.*, **16** [11] 355 (1937). (*b*) F. M. Jaeger, Optical Activity and High Temperature Measurements. McGraw-Hill Publishing Co., Ltd., London (1930); *Ceram. Abs.*, **10** [7] 527 (1931); see also F. M. Jaeger, *Z. anorg. allgem. Chem.*, **101**, 1–214 (1917).

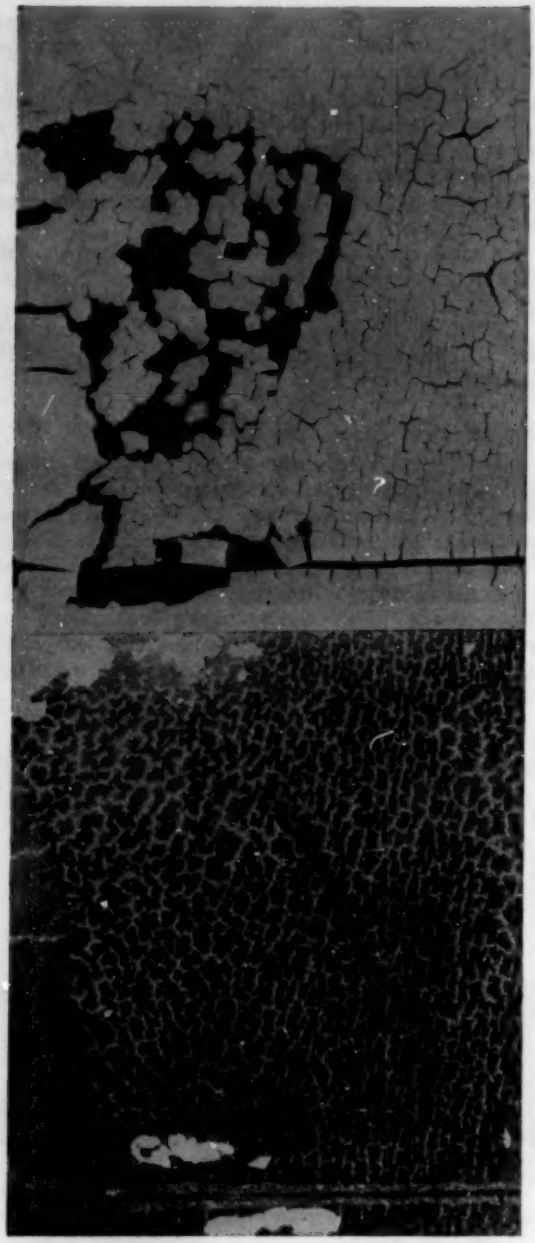


FIG. 5.—(*Top*) Enamel containing boric acid shows severe tearing; (*bottom*) deposition of boric acid on the ground coat in identical patterns with the tearing lines of the cover coat.

(5) Theory of the Causes of Tearing

Experimental work indicates that boric acid causes

FIG. 6.—Influence of the ratio of Na_2O to B_2O_3 on the tearing of enamels; each piece is 4 by 6 in.

tearing. Early in the drying process, a large proportion of the capillary openings are sealed, broken, and obstructed by the salt deposited on the surface. This impedes further diffusion of the water to the surface. Cracks, which extend in random fashion across the surface, develop in the enamel owing to the drying shrinkage and case hardening of the film. Capillary attraction draws the water entrapped beneath the surface to the cracks, where it evaporates and deposits the salts which it contains. This may be the cause of the pattern on the ground coat shown in Fig. 5. This pattern is identical with and congruent to the tear lines and cracks in the cover-coat enamel.

Early in the firing process, the boric oxide compounds expand and exert rending forces which tend to rupture the weak, inert films of enamel. Because of its high surface tension and viscosity, melted boric acid tends to cause tearing by drawing the enamel together to form balls. The enamel film, already cracked and broken by the internal forces, offers little resistance to

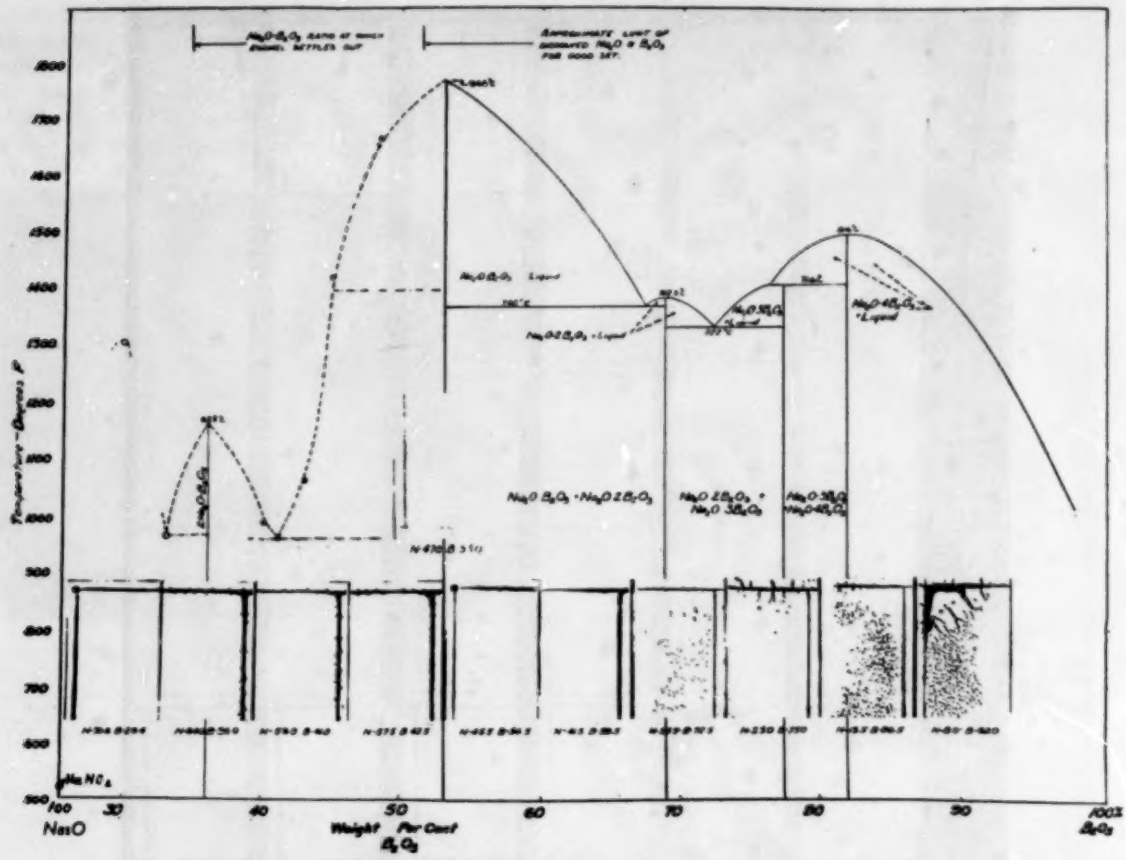


FIG. 7.—Relation of the ratio of Na_2O to B_2O_3 to the tearing resistance of enamel films; full line diagram after Morey and Merwin[12(a)]; dashed line liquidus as of this study.

the tearing forces of the molten material. The melted boric acid at the surface further seals the pores, which permits a lifting effect of the escaping gases by reducing their avenues of escape.

An increase in firing temperature decreases the effect of boric acid by reducing its surface tension and viscosity, and the strength of the enamel film is increased by the fusion of the frit. If enamel films are once cracked or broken, it is difficult for them to heal during firing because of the high surface tension and the viscosity of the glass.

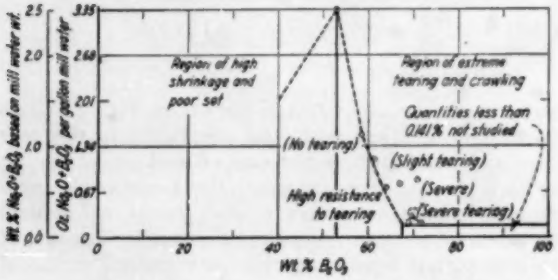


FIG. 8.—Relation of the ratio of Na_2O to B_2O_3 and the total quantity of these oxides present in the mill liquor to the tearing resistance.

In addition to the effect of the surface tension of the molten salts on tearing, the influence of the viscosities of these melts is also important. Changes in composition and temperature have a far greater effect on the viscosity than the surface tension of such melts.[12(b)] Because both the quantities and the compositions of these salts vary widely in enamels and because the temperature changes from room temperature to 1500°F. and higher in the brief time the enamels are fired, the viscosities of these molten salts constitute an important factor which influences the film strength of the enamel.

(6) Improvement of Film Strength

The influence of the ratio of Na_2O to B_2O_3 on tearing resistance is shown in Figs. 6 and 7. A severe curling and tearing developed in enamels with a low ratio of Na_2O to B_2O_3. The entire enamel surface was covered with typical crowfoot tearing. Increased ratios reduced this tearing, and the best resistance to tearing was obtained at a ratio of 0.89, which is that of sodium metaborate. Ratios from 0.89 to approximately 0.55 offered good but decreasing resistance to tearing. The actual ratio in this range at which tearing appears depends on the total quantity of salts in the slip. Ratios

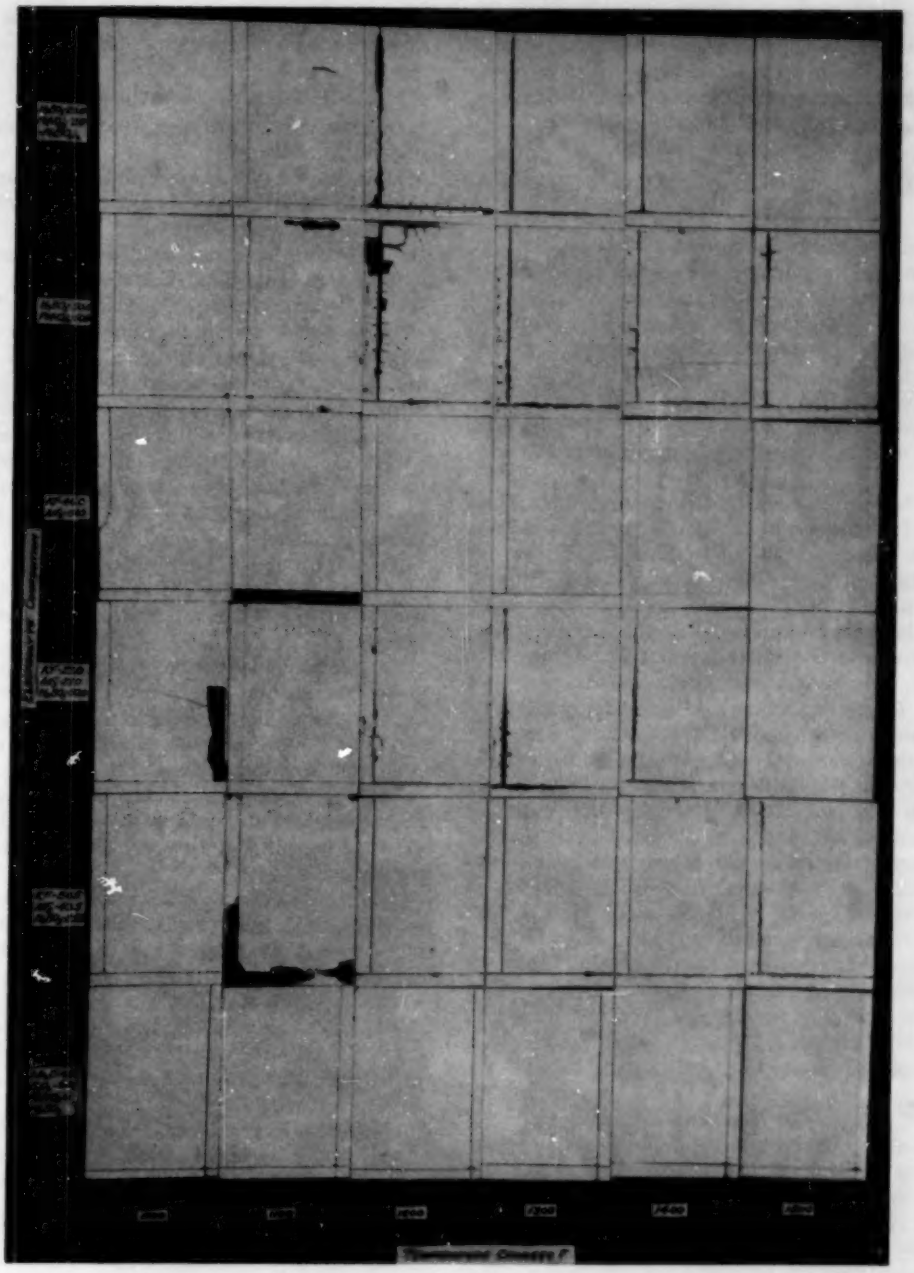


FIG. 9.—Effect of various soluble salts on the tearing resistance of enamels.

of less than 0.55 permit tearing even with very small amounts of salt present; and, as the total salt content increases, the closer is the ratio of 0.89 approached by corrective additions of salts to prevent tearing and to give maximum film strength. Figure 8 shows graphically the relation between the total quantity of salt, the ratio of Na_2O to B_2O_3, and the tearing resistance.

In a system of clay, water, and electrolytes, such as sodium nitrite and boric acid in equimolecular proportions, definite reactions are indicated which are initiated by the clay. Any reaction between boric acid and sodium nitrite alone at room temperature probably is reversed by the presence of nitrous acid formed by the ionization of the sodium nitrite. When clay is present, it is possible that the formation of nitrous acid no longer completely prevents the reaction between the other electrolytes inasmuch as part of the H^+ ions are removed from the system by adsorption on the clay. By removing part of the product of the reaction, it proceeds more completely to form the metaborate.

Of great importance also is the fact that, because nitrous acid is unstable, the reaction is driven toward completion by the application of heat. Although the reaction itself is evidently more complicated in an enamel slip, the final result probably may be represented by a simpler expression as follows:

$$NaNO_2 + H_3BO_3 + \text{clay} + \text{heat} = NaBO_2 + H^+ \text{clay} + NO_2\uparrow + H_2O.$$

Sodium nitrite markedly increases the set of enamel slips, whereas sodium hydroxide in the same proportions either decreases the set or has no effect. The increased set accompanying the addition of sodium nitrite indicates an increased flocculation of the clay fraction, which is consistent with the adsorption of hydrogen by the clay. During the drying of the enamels, moreover, the heat favors the reaction because the nitrous acid is increasingly unstable at higher temperatures.

Because sodium metaborate is more soluble than boric acid, it remained in solution longer and did not congest the capillaries as did boric acid. The water therefore diffused to the surface more easily, drying took place more uniformly, cracks rarely formed in the film, and the salts concentrated at the surface. Furthermore, because the salt concentration occurred at the surface, volume changes during dehydration were harmless. Disruption caused by boric acid was most severe between 1000° and 1200°F. because the boric acid was most active, and during this period the enamel was most fragile. Sodium metaborate caused no tearing because it is inert at temperatures below 1300°F. As the enamel fused, however, it gained strength, and the metaborate was taken into solution without evolving gases to injure the enamel.

In the event that all of the boric acid and sodium nitrite or other corrective salt fails to react in the slip, sodium metaborate can be formed during firing. Sodium nitrite, melting at a low temperature to form a very mobile melt, diffuses through the film and rapidly dissolves and combines with the boric acid, reduces the expansion of the latter, and prevents rupture of the film.

This study also shows that enamel film strength and tearing resistance cannot always be improved by additions of low melting salts; for example, several low melting salts of lithium, potassium, and lead caused severe defects. Brushed edges were masked and run over, the films were easily dislodged, and poor surfaces were developed (see Fig. 9).

The success of some salts and the failure of other salts to eliminate tearing is a function of their anions. During heating, for example, the nitrite portion of sodium nitrite volatilized completely without harming the film; sodium nitrate, on the other hand, caused severe blistering owing to the evolution of gas after the fusion of the film. Fluoride salts in general were too refractory and produced scummed and pitted surfaces. It is obvious, therefore, that the choice of salts depends not only on the ability of the salt to form the metaborate but also on the absence of undesirable characteristics associated with the salt anion.

IV. Conclusions

Observations of the results of this study offer the following conclusions.

(1) Increased fineness of grinding increases the total solution of the frit, but it is more of a leaching process than a true, uniform solution.

(2) No definite correlation seems to exist between particle size, shape, and size distribution and enamel film strength except that the coarser particles are more resistant to tearing than finer ones.

(3) The pH values of the mill liquors approach a condition of equilibrium on continued grinding.

(4) Sodium fluoride is the most abundant of the materials extracted from the frit during milling which concentrate as salts at the film surface during drying. Other salts include borax, sodium metaborate, sodium metasilicate, sodium carbonate, sodium sulfate, and silica-alumina gel.

(5) Because of the high buffering properties of solutions of these salts, the pH values of the slips and mill liquors fail to serve as criteria for slip control and film strength.

(6) The principal cations contributed by the frit to the slip are sodium, potassium, and calcium.

(7) Sodium phosphate facilitates grinding by increasing the total base-exchange capacity of the clay through anion exchange of the phosphate.

(8) The degree of consolidation and the properties of the dry enamel film are probably influenced by the base-exchange capacity of the clay and the kind of cation which is adsorbed.

(9) Although many other salts in enamel slips are associated with film strength, the predominating materials responsible for poor film strength are boric acid and compounds with a high borate content, such as borax.

(10) This study has indicated that sodium nitrite and other salts prevent tearing by converting most of the boric acid in the system to sodium metaborate.

(11) From the standpoint of slip control and ease of elimination of the volatile anion, sodium nitrite is the best of the salts investigated for introducing sodium ions into the slip. Many other salts, however, might be employed if suitable precautions are observed in their use.

(12) The behavior of systems of soluble salts, such as exist in enamels below the fusion of the frit, definitely influences the brushing qualities, the film strengths, and the finished surfaces of enamels.

The study of these salts as a system independent of the frit is a new point of view that has been developed by this investigation. This concept offers an opportunity for further research in the study of the film strength of enamels.

Department of Ceramic Engineering
University of Illinois
Urbana, Illinois

CERAMIC ABSTRACTS

Compiled by the

AMERICAN CERAMIC SOCIETY

Ross C. PURDY, Editor

ABSTRACTERS

J. B. Austin, A. A. Ayars, L. R. Barrett, K. W. W. Bartlett, A. C. Bevan, D. A. Biddle, A. Bidduiph, P. P. Budnikov, J. C. Chaston, W. M. Cohn, M. V. Condoide, P. S. Dear, Frank Fisher, W. D. Foster, V. D. Fréchette, J. L. Gallup, J. D. Gat, R. A. Gregory, Robert Halle, Max Hartenheim, J. J. Hazel, F. G. Heck, R. A. Heindl, P. G. Herold, W. H. Herschel, M. B. Hill, F. J. Hurlbut, G. M. Hutt, J. F. Hyde, Herbert Insley, C. B. Jenni, B. Z. Kamich, B. E. Kinkulkin, G. A. Kirkendale, W. D. Klugman, Yosio Kora, R. Kunin, B. B. Lane, C. H. Lemke, W. Loewenthal, F. S. Mallette, V. S. de Marchi, L. F. May, E. H. McClelland, J. M. Noy, E. C. Pierce, Alexis Pincus, M. E. Poor, Katherine Reed, H. K. Richardson, R. A. Ronnebeck, B. C. Ruprecht, A. B. Searle, Stanford Setchell, Lucille Shattuck, G. R. Shelton, H. E. Simpson, A. P. Som, F. E. Sonnenschein, E. Stefanowski, A. G. Stern, B. H. Strom, M. Takei, L. E. Thiess, Hans Thurnauer, E. J. Vachuska, F. J. Zvanut

JOURNAL REFERENCE: The journal name appears in italics, followed by the volume (bold-faced), issue number (in brackets), page numbers, and year (in parentheses).

May, 1941
20—5

Abrasives

Cutting with abrasives. R. R. WIESE. *Amer. Machinist*, **85** [4] 97–100 (1941).—Continued improvement of the bonds which hold the abrasives has made it possible to cut bar stock up to 2 in. and tubing up to $3^1/_2$ in. in diameter. Dry cutting is used where high production is wanted and high finish is not so important. Surface speeds of 9000 to 12,000 ft. per min. are used; for non-ferrous materials and alloy steels, speeds up to 16,000 ft. per min. are used. In wet cutting a coolant is used to keep the temperature of the work down, and cutting can be done at lower speeds, resulting in a cleaner cut and reduced wheel wear. Lower cost rubber-bonded wheels can be used; the surface speeds range from 7500 to 10,000 ft. per min. Submerged cutting is employed for heat-sensitive steels, thin-wall copper tubing, plastics, and any sections where heat must be kept to a minimum. Metallographic specimens require only slight polishing when cut by this method. Rubber-bonded wheels are usually used, but resinoid wheels are used for cutting plastics. The best results are obtained with surface speeds of 5000 to 6000 ft. per min. The types of wheels recommended for the different purposes are given. M.H.

PATENTS

Abrasive. WILLIAM E. CATLIN (Canadian Industries, Ltd.). Can. 394,791, Feb. 25, 1941 (Feb. 1, 1939). G.M.H.

Abrasive alumina. BLAKESLEE BARNES (Chemical Construction Corp.). Can. 394,802, Feb. 25, 1941 (Aug. 29, 1938; in U. S. Sept. 22, 1937). G.M.H.

Abrasive article. BAKELITE, LTD. Brit. 532,952, Feb. 19, 1941 (Aug. 5, 1938).

Abrasive cutoff machine. B. G. HARDY (A. P. de Sanno and Son, Inc.). U. S. 2,232,387, Feb. 18, 1941 (June 13, 1938).

Abrasive tool. GUSTAV BONWITT. U. S. 2,233,469, March 4, 1941 (Feb. 9, 1940).—An elongated carrier for abrasive sheets.

Abrasive wheel. EDWARD VAN DER PYL (Norton Co.). Can. 394,607, Feb. 11, 1941 (Nov. 12, 1940). G.M.H.

Apparatus for fastening shafts on grinding machines. OTTO K. BLEY. Ger. 689,120, Feb. 22, 1940 (Oct. 25, 1938); XII/67*a*. 10. D.A.B.

Apparatus for grinding cylindrical workpieces between two abrasive wheels. SCHUMAG SCHUMACHER METALLWERKE A.-G. FÜR PRÄZISIONSMECHANIK. Ger. 689,078, Feb. 22, 1940 (April 26, 1938); XII/67*a*. 24.01. D.A.B.

Apparatus for grinding and polishing irregular-shaped articles. ANTOINE SALVANEIX. Ger. 682,369, Sept. 28, 1939 (Dec. 1, 1936); XII/67*a*. 29. D.A.B.

Apparatus for surface grinding and polishing of hard materials, i.e., stone. SOC. MARBRIÈRE DE PARIS. Ger. 680,641, Aug. 17, 1939 (March 27, 1937); XII/67*a*. 14. D.A.B.

Apparatus for truing grinding and abrasive wheels. E. A. COOKE (Kapella, Ltd.). U. S. 2,234,539, March 11, 1941 (April 10, 1939).

Bonded abrasive. N. P. ROBIE (Carborundum Co.). Can. 394,084, Jan. 21, 1941 (Sept. 29, 1938; in U. S. Sept. 30, 1937). G.M.H.

Crankpin grinder. W. L. GROENE (R. K. Le Blond Machine Tool Co.). U. S. 2,232,228, Feb. 18, 1941 (May 10, 1940). U. S. 2,232,229, Feb. 18, 1941 (May 20, 1940).

Crankshaft grinder. A. J. BRAZIL (E. L. Cooper and E. L. Berner). U. S. 2,235,417, March 18, 1941 (Aug. 19, 1939).

Disk-shaped abrasive tool for working level surfaces of hard material such as marble or glass. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY. Ger. 682,749, Oct. 5, 1939 (Nov. 1, 1934); XII/67*a*. 14. D.A.B.

Gear-finishing machine. S. M. SHAW (Michigan Tool Co.). U. S. 2,232,408, Feb. 18, 1941 (Nov. 25, 1935).

Grinding or abrading machines. A. NAGY. Brit. 533,246, Feb. 19, 1941 (Oct. 21, 1939).

Grinding or honing devices. MICROMATIC HONE CORP. Brit. 533,464, Feb. 26, 1941 (Feb. 18, 1939).

Grinding machine. J. A. HARROLD (Herman Pollack). U. S. 2,233,312, Feb. 25, 1941 (Aug. 23, 1939). M. I.

MATHEWSON AND A. L. KRAUSE (Brown and Sharpe Mfg. Co.). U. S. 2,235,558, March 18, 1941 (Nov. 14, 1935; Oct. 4, 1937).

Grinding material. C. H. COMMONS, JR. (Titanium Alloy Mfg. Co.). U. S. 2,233,585, March 4, 1941 (Oct. 11, 1940).—As a grinding material, a finely divided composition containing zirconium silicate, clay, and an auxiliary flux.

Grinding or regulating wheels for grinding machines. LIDKÖPINGS MEKANISKA VERKSTADS AKTIEBOLAG. Brit. 533,312, Feb. 26, 1941 (Aug. 12, 1938).

Grinding of screw threads. CHURCHILL MACHINE TOOL CO., LTD., AND H. K. ASBRIDGE. Brit. 532,053, Jan. 29, 1941 (Aug. 15, 1939).

Grinding wheels. NORTON GRINDING WHEEL CO., LTD. Brit. 532,232, Jan. 29, 1941 (Aug. 24, 1938).

Honing or lapping machines. A. F. BURGESS (Barnes Drill Co.). Brit. 532,651 and 532,652, Feb. 12, 1941 (Sept. 19, 1939).

Knife sharpener. R. M. NORTON (A. W. Holmberg & Co.). U. S. 2,232,402, Feb. 18, 1941 (Dec. 21, 1939).

Manufacture of abrasive articles. NORTON GRINDING WHEEL CO., LTD. (Norton Co.). Brit. 533,363, Feb. 26, 1941 (Aug. 11, 1939).

Manufacture of abrasive-coated articles. R. L. MELTON AND R. C. BENNER (Carborundum Co.). U. S. 2,233,175, Feb. 25, 1941 (March 28, 1940).

Manufacture of bonded abrasive articles. R. L. MELTON AND G. L. CHAPMAN (Carborundum Co.). U. S. 2,233,176, Feb. 25, 1941 (March 28, 1940).

Metal-bonded abrasive articles. W. J. TENNANT (Carborundum Co.). Brit. 532,890 and 532,891, Feb. 12, 1941 (July 31, 1939).

Producing abrasives in sheet form. MINNESOTA MINING & MFG. CO. Ger. 689,202, Feb. 22, 1940 (Feb. 10, 1934); XII/67*e*. 1. D.A.B.

Producing grinding wheels. KURT SELLIN (Peter Fuchs Erste Naxoschmirgelfabrik Deutschlands). Ger. 680,994, Aug. 24, 1939 (Jan. 29, 1938); VI/80*b*. 11.—Abrasive wheels are produced from a mixture of abrasive particles and a binding agent which is subjected to pressure after a complete or partial drying process. D.A.B.

Resin-bonded abrasive article. S. S. KISTLER AND C. E. BARNES (Norton Co.). U. S. 21,736, March 4, 1941 (Sept. 3, 1940); reissue of original 2,189,733, Feb. 6, 1940 (Jan. 28, 1938). U. S. 21,737, March 4, 1941 (Sept. 3, 1940); reissue of original 2,189,734, Feb. 6, 1940 (Jan. 28, 1938). U. S. 21,738, March 4, 1941 (Sept. 3, 1940); reissue of original 2,189,735, Feb. 6, 1940 (Jan. 28, 1938).

Safety device for grinding machines. GUSTAV ROSENKE. Ger. 682,368, Sept. 28, 1939 (Feb. 8, 1938); XII/67*a*. 28.—The apparatus provides for the suction and settling of falling dust. D.A.B.

Screw thread grinding machine lead compensator. F. B. HUGHES. U. S. 2,232,704, Feb. 25, 1941 (March 21, 1940).

Segmental abrasive wheel. L. A. PATT (Carborundum Co.). Can. 394,409, Feb. 4, 1941 (July 3, 1939; in U. S. Feb. 23, 1939). G.M.H.

Sharpening or honing appliance. K. PARK. Brit. 532,014, Jan. 29, 1941 (Aug. 12, 1939).

Tools for dressing grinding wheels. COVENTRY GAUGE & TOOL CO., LTD., S. J. HARLEY, AND J. E. WAINWRIGHT. Brit. 533,002, Feb. 19, 1941 (Oct. 17, 1939).

Unit for diamond grinding. FRITZ SCHWARZ. Ger. 681,038, Aug. 24, 1939 (March 14, 1938); XII/80*d*. 2. D.A.B.

Valve seat grinder mechanism. C. A. OLSON (Lisle Corp.). U. S. 2,232,340, Feb. 18, 1941 (July 5, 1938).

Wet grinding attachment for valve resurfacing machine. G. C. WILHIDE (Black & Decker Mfg. Co.). U. S. 2,233,568, March 4, 1941 (Aug. 26, 1939).

Art and Archeology

American way. J. W. *Magazine of Art*, **33** [11] 626–29 (1940).—W. describes an enterprise of a cooperative of American designers, craftsmen, manufacturers, and retailers. Illustrations show a duck designed by Katherine McNab of Oregon Ceramic Studios, California ceramics by Glen Lukens, glassware designed by Joseph Platt, pottery by Peter Caboi and Douglas Maier, and dinnerware designed by Audrey Buller and made by the Edwin M. Knowles China Co. M.E.P.

Black pottery culture in Chekiang. STERLING S. BEATH. *Asia*, **41**, 47–51 (1941).—B. describes the findings at two new sites near Hangchow in Chekiang Province. This pottery is of the Neolithic age and is typically thin, shiny, and covered with a black glaze. Another type is thicker and is black outside and gray within. Much of the pottery was made on a wheel and was probably burnished on a wheel. The ware points to a high development of the wheel technique. Most of the ware was made for use, but some was for ceremonial purposes. Holes were frequently found in the pottery, but their purpose is not known. It is believed that the black-pottery people laid the foundation for Shang civilization, as their stem cups and wine cups are similar in shape to Shang bronzes. W.D.F.

Dig at Begram, 1939: I and II. JOSEPH HACKIN. *Asia*, **40**, 525–28, 608–12 (1940).—Begram is 45 miles north of Kabul, Afghanistan. Several plaster plaques were discovered, some in low relief and others combining low and high relief. A pottery jug shows a remarkable example of lead or tin glazing; this type of jug was made in the 1st and 2d centuries A.D. Painted glass goblets, a glass wine pitcher with gold-leaf decoration, and a glass cup with the transparency of crystal were also found. Many Indian ivories and some Chinese lacquer were uncovered showing that this period was unusually propitious for foreign trade. W.D.F.

Examination of "Egyptian blue" by X-ray powder photography. E. M. JOPE AND G. HUSE. *Nature*, **146** [3688] 26 (1940).—Examination by X-ray powder photography of various examples of the brilliant azure pigment known as "Egyptian blue" showed that several from different sources had the same crystal form. All of these contained essentially copper, calcium, and silica with varying small amounts of sodium. Laurie and others had previously shown that examples of a similar blue from other sources consisted essentially of a definite compound, $CuO \cdot CaO \cdot 4SiO_2$, which assumes this brilliant azure only if formed between 800° and 900°C. A study by X-ray powder photography of the blue powder on a pot from Tel-el-Amarna identified the blue color as being due to $CuAl_2O_4$. J.L.G.

Ezion-Geber. NELSON GLUECK. *Asia*, **40**, 663–69 (1940).—The intricate smelter refinery was considered the most important structure. To strengthen its walls, a structure similar to a fortification glacis was built, and the outer side was smoothed over with mud mortar. The brick were laid in a complex diagonal crisscross pattern. These walls were 12 ft. high. Rooms for use as foundries and factories were built around the refinery. A square of outer fortification walls was also built. This (Period I) was destroyed by the Egyptian king, Shoshenk. It was reconstructed (Period II) with very heavy fortifications, possibly by Jehoshaphat of Judah. One burial was found in which there were some three-handled jars. The brickyard and some completed but unused brick were discovered. In Period III, the town was probably rebuilt by Uzziah. The Edomites captured and destroyed it and then rebuilt it (Period IV). The jars stamped with a royal seal probably belong to this period. Other jars found were filled with a sweet-smelling resin. After destruction it was rebuilt (Period V). To this period belong some Greek sherds of about the 4th century B.C. See "Gateway. . .," *Ceram. Abs.*, **18** [11] 289 (1939). W.D.F.

Islamic finds at Tarsus. FLORENCE E. DAY. *Asia*, **41**, 143–48 (1941).—The first finds cover the period from the 7th to the 10th century. Both glazed and unglazed speci-

mens of Umayyad pottery were found. This pottery was made in molds, with designs in relief and a green lead glaze. This ware has been found here only. A wide, shallow bowl found was either Umayyad or very early Abbasside. It was made of red clay with a fine white slip both inside and out and was variously decorated in green, brown, yellow, and white. This type was first found at Samarra in Iraq and was derived from T'ang pottery. Other ware of the type found at Samarra included (1) ware of red clay, made in a mold, with a lead glaze and covered with gold luster inside and out; the designs were influenced by both Greek and Iraq art; (2) ware of yellow clay, with a white tin glaze, painted with luster in three tones (green-gold, warm gold, and dark brown); and (3) ware with a white tin glaze and designs of cobalt blue. One piece of T'ang Chinese pottery was dug up. Aside from much coarse common unglazed pottery, the most abundant ware found was a north Syrian ware of heavy red clay, with designs on the clay and a thin lead glaze over it. Many types of Abbasside pottery from Iraq, such as bowls decorated on the inside with animals, were reproduced locally. A small amount of glass was found. The Christian interregnum from the 10th to 13th century left very little. To the 13th to 15th centuries belong a Mameluke sgraffito ware much like an earlier ware, Mameluke pottery from Egypt, and Miletus ware. See "Mound . . .," *Ceram. Abs.*, **18** [10] 263 (1939). W.D.F.

Italian terra-cotta relief from a series dated 1513. HELEN COMSTOCK. *Connoisseur*, **106** [470] 164 (1940).—This series of fifteen glazed bas-reliefs of New Testament scenes acquired by the Minneapolis Institute of Arts has been assigned tentatively to Santi Buglioni, nephew of the Buglioni who was a rival to the Robbia workshop. The panels of this collection are pleasing in color, dominated by blue, red, green, and yellow. Illustrated. M.E.P.

Medieval heraldic glass in Surrey churches: II. F. SYDNEY EDEN. *Connoisseur*, **106** [470] 143–46 (1940).—The windows found in churches at Lingfield, Crowhurst, and Shere are described. Many of these are still largely made up of the original glass dating from the 12th to the 16th century, although parts of them have been repaired and replaced through the years. Illustrated. For Part I see *Ceram. Abs.*, **20** [1] 4 (1941). M.E.P.

Ming vase of baluster form. *Connoisseur*, **106** [471] 180 (1940).—A full-page color illustration of an enamel-decorated vase of the Ming period (Chêng-Hua, A.D. 1465–1487) from the S. D. Winkworth collection. M.E.P.

Pre-Columbian Andean art: II, Pottery. PHILIP AINSWORTH MEANS. *Magazine of Art*, **33** [11] 632–37 (1940).—The native civilized peoples of pre-Columbian America had no mechanical aids and depended largely on brute strength to perform imposing tasks. The examples of early Chimu pottery show the prominence of realism. A portrait pot of about A.D. 200–300 is a sculptured head showing a countenance surmounted with decorated cloth cap and hair. The symbolized aspect of the art of this period is shown in a pot roughly shaped like a frog. It is nearly all covered with white slip on which is painted a curious stylized scene showing a man beset by sea creatures and land beasts, the perennial struggle between man and the ocean, the latter aided by allied hostile forces on the land. The early Nasca pottery exemplifies the carry-over of Chimu realism into a quasi-realistic style. A lovely bowl with geometric decoration (about 600) illustrates the fusion of Early Nascu with Tiahuanaco I. The Classical Tiahuanaco II period (700–900) examples show how angularity of line, with almost complete loss of realism and with rich coloring, represents life forms with sureness but with little or no reference to the natural models. After the downfall of Tiahuanaco II civilization (900), no pottery of note was produced for 300 years. When the Incas spread their culture over the whole Andean area (around 1200), ceramics grew from a fresh and humble start to a new high excellence. Their shapes and designs were almost wholly their own. Comparatively little of it has survived to our time. It is marked by use of small geometric patterns with rare reference to life forms. The most original and characteristic contribution of the Incas was a new form of pot, the aryballus, a shape possessed of dynamic symmetry. It was held against the carrier's back with a rope which passed through handles, over a nubbin near the base of the neck, and across the carrier's forehead or chest. The aryballus was the supreme achievement of the Incaic potter. Illustrated. For Part I see *Ceram. Abs.*, **20** [1] 5 (1941). M.E.P.

Rare Liverpool marks and pieces. H. BOSWELL LANCASTER. *Connoisseur*, **106** [470] 147–49 (1940).—There are many lesser known potters and their work from Liverpool in addition to the well-known transfer-printed and blue and white ware. The *Liverpool Advertiser*, 1756, tells of pottery and craftsmen not yet identified in modern times. One of the rarest known marks is Seth Pennington's letter "P" in the same color as the ware decoration. A rare mark of the Herculaneum factory recently discovered is a picture of a paddle steamer which is also equipped with three masts and a bowsprit, below which is the word "Liverpool." There are few known examples of the work of Philip Christian, whose unmarked porcelain is easily identified, and nothing is known of his origin. He imitated ware then being introduced in Staffordshire, i.e., salt glaze and mottled glazes of Whieldon. The Liverpool pieces offer a little worked field for research. Illustrated. M.E.P.

Relation between microstructure and method of preparation of ceramic materials from Samarra. K. OBENAUER. *Ber. Deut. Keram. Ges.*, **20** [1] 11–18 (1939).—In the excavations of Samarra, northwest of Bagdad, fragments of whiteware, stoneware, and porcelain dating from 838 to 883 were found. According to F. Sarre, some of these are the oldest dated porcelain, while P. Kahle believes them to have been imported from China. O. attempted to determine microscopically how the bodies were prepared, since chemical analysis gives no information about the possibly recognizable minerals or the changes in the glazes due to firing. Seven fragments were examined, i.e., four of stoneware, two of whiteware, and one of porcelain. In a thin section, quartz could chiefly be seen in the ceramic bodies as remaining mineral and, less frequently, rutile and zircon. In all pieces the quartz appeared in extremely sharp-cornered crystal fragments; from this, O. concludes that, in preparing the materials, large pure quartz pieces were artificially crushed. This suggests that the porcelain stone referred to in the ancient literature was quartz crystals or pure quartz sand. The refractive index of the glazes varied from 1.51 to 1.70. There appeared to be both earth and metal glazes. Details are given concerning the microstructure of the bodies and the chemical composition of the glazes. W.H.H.

Zenith of the German stained glass art in the 14th and 15th centuries. J. L. FISCHER. *Diamant*, **62** [5–6] 31–33 (1940).—The development of German glass staining into a high art began in the 13th century. Up to this time a strongly two-dimensional aspect prevailed, but the ascetic appearance of figures was abandoned in the 14th century, and three-dimensional, perspective pictures gave a life-like expression to scenes and figures. This trend started in the monastery of St. Francis in Assisi and was continued in Germany where it was developed to the highest extent. Photographs are given of several examples of church windows and civic buildings. After 1500 this type was gradually abandoned under the influence of the renaissance era in Italy. M.H.

BOOK

Ceramic Art (Keramische Kunst). MAX LAEUGER. A. Beig, Pinneberg near Hamburg, 1939. 160 pp., 76 color prints, 80 illustrations. Price Rm. 30. Reviewed in *Ber. Deut. Keram. Ges.*, **20** [11] 492 (1939).—The book is of great and permanent value for every ceramic artist. L. has been active both in inside and outside architecture and in city planning. He taught for 40 years at the Karlsruhe Technical School and has published many books. That he is master of the most varied glazing techniques is evident from the numerous colored illustrations. W.H.H.

PATENTS

Ceramic color. W. D. STILLWELL (Harshaw Chemical Co.). U. S. 2,234,920, March 11, 1941 (March 15, 1939).—A ceramic pigment material contains oxides of tin, chromium, and copper, the chromium and copper oxides together amounting to more than 1% and less than 5% of the weight of the tin oxide.

Decorating articles of glass, porcelain, ceramic materials, or enameled metal. WÜRTTEMBERGISCHE METALLWARENFABRIK. Ger. 688,618, Feb. 8, 1940 (June 9, 1937); VI/32*b*. 9.—A layer of polishing silver consisting of a mixture of finely divided silver and a fluxing agent is applied as a binding agent between the parts to be joined together. The parts are joined together by adhesion and united together by fusion by firing at 550° to 600°C. The polishing silver layer can then be polished. D.A.B.

Designs for:

Bottle. W. J. LUNDY (Olean Glass Co.). U. S. 125,622, March 4, 1941 (Jan. 10, 1941). U. S. 125,920, March 18, 1941 (Jan. 10, 1941). FRANK MCINTOSH (Lentheric, Inc.). U. S. 125,899, March 18, 1941 (April 5, 1940). U. S. 125,921 and 125,922, March 18, 1941 (June 21, 1940).

Bottle. NORTHAM WARREN, LTD. Can. 12,940, Jan. 9, 1941. G.M.H.

Bottle. PEPSI-COLA CO. OF CANADA, LTD. Can. 12,960, Feb. 3, 1941. G.M.H.

Bottle stopper. A. I. LORENZEN (Owens-Illinois Glass Co.). U. S. 125,896 to 125,898, March 18, 1941 (Dec. 14, 1940).

Building block. MARLEY TILE CO., LTD. Can. 12,949 and 12,950, Jan. 22, 1941. G.M.H.

Building block. ERNST STEINHARD. U. S. 125,789, March 11, 1941 (July 30, 1940).

Coffee maker. R. I. FELVER (Westinghouse Electric & Mfg. Co.). U. S. 125,266, Feb. 18, 1941 (Oct. 24, 1940).

Combined reflector and prismatic bowl for lighting fixtures. T. W. ROLPH AND H. L. LOGAN (Holophane Co., Inc.). U. S. 125,928, March 18, 1941 (Aug. 18, 1938).

Combined water closet tank and bowl. B. B. PIESLAK (Abingdon Sanitary Mfg. Co.). U. S. 125,902 and 125,903, March 18, 1941 (July 12, 1940).

Drinking glass. GORMAN, ECKERT & CO., LTD. Can. 12,956, Jan. 31, 1941. G.M.H.

Glass bottle. L. J. KIHN (J. T. & A. Hamilton Co.). U. S. 125,637, March 4, 1941 (Jan. 4, 1941). U. S. 125,638, March 4, 1941 (Jan. 8, 1941).

Glass nappy. A. J. DREITZER (Pitman-Dreitzer & Co., Inc.). U. S. 125,264, Feb. 18, 1941 (Jan. 8, 1941). BELLE KOGAN AND A. H. NICHOLSON (Federal Glass Co.). U. S. 125,275, Feb. 18, 1941 (Dec. 16, 1940).

Glass plate. A. J. DREITZER (Pitman-Dreitzer & Co., Inc.). U S. 125,263, Feb. 18, 1941 (Dec. 27, 1940).

Glass tumbler. A. H. NICHOLSON (Federal Glass Co.). U. S. 125,901, March 18, 1941 (Jan. 21, 1941).

Goblet. GEORGE SAKIER (Fostoria Glass Co.). U. S. 125,289 and 125,291, Feb. 18, 1941 (Oct. 24, 1940).

Jar. J. J. BLUM (Owens-Illinois Glass Co.). U. S. 125,607, March 4, 1941 (Dec. 28, 1940). B. D. FUERST (Owens-Illinois Glass Co.). U. S. 125,616, March 4, 1941 (Dec. 28, 1940).

Lighting fixture bowl. T. W. ROLPH AND H. L. LOGAN (Holophane Co., Inc.). U. S. 125,929, March 18, 1941 (Aug. 18, 1938).

Plate. J. C. DE KORT (Scammell China Co.). U. S. 125,304, Feb. 18, 1941 (Dec. 23, 1940). C. W. LEIGH (Morimura Bros., Inc.). U. S. 125,935 and 125,936, March 18, 1941 (Jan. 27, 1941). A. W. MACKENZIE, JR. (Meakin & Ridgeway, Inc.). U. S. 125,623, March 4 1941 (Dec. 21, 1940). GEORGE SAKIER (Fostoria Glass Co.). U. S. 125,574, March 4, 1941 (Oct. 24, 1940).

Refracting bowl for lighting fixtures. T. W. ROLPH (Holophane Co., Inc.). U. S. 125,316, Feb. 18, 1941 (June 26, 1940).

Device for harmonizing colors. D. E. ROWE (Kroehler Mfg. Co.). U. S. 2,234,609, March 11, 1941 (Sept. 25, 1939).

Cements

Exact measurement of the thermal reaction of cement by the Thermos bottle method. JEAN CLÉRET DE LANGAVANT. *Rev. Matériaux Construction Trav. Publics*, No. 348, pp. 161–65; No. 349, pp. 181–88; No. 350, pp. 208–13 (1938).—A method is presented which gives very exact measurements of the heat liberated during the hydration of cement. It is based on the principle of the adiabatic oven and utilizes the inexpensive Thermos bottle found on the market in the apparatus which is automatic. A complete explanation of the operation of the apparatus is given. M.V.C.

Portland cement—theories (proven and otherwise) and specifications. P. H. BATES. *Proc. Amer. Soc. Testing Materials*, **40**, 469–500 (1940).—B. discusses the definition of Portland cement, its history, what it is, reactions of cement with water, new specifications for cement, fineness, the autoclave test, resistance to weathering, admixtures, proposed tests for Portland cement, and the effect of manufacture on the properties. See "Theories . . ." *Ceram. Abs.*, **20** [1] 6 (1941). R.A.H.

SEPARATE PUBLICATION

Production, Employment, and Output Per Man in Gypsum Mining. ROBINSON NEWCOMB AND KNUTE PETERSON. *U. S. Bur. Mines Information Circ.*, No. 7134, 3 pp. Free.—The major results obtained in a study of gypsum mining made by the Bureau of Mines in cooperation with a WPA National Research Project are presented. R.A.H.

PATENTS

Cement comprising magnesia and copper chloride and articles made therefrom. T. A. MITCHELL AND D. C. MITCHELL (Palos Verdes Laboratories Corp.). U. S 2,234,080, March 4, 1941 (March 16, 1938).—A cement comprising magnesia constituting at least 15% by weight of the mass together with a granular material and a reagent substantially free from magnesium chloride which comprises copper chloride sufficient to react with substantially all of the amount of magnesia in the presence of water and set as a hard cement that is not materially disintegrated by water.

Enamel

Containers for hydrofluoric acid and other acid and pickling baths. ZSCHACKE. *Diamant*, **62** [29–30] 193–96 (1940).—For economy, containers of Monel, nickel, or lead or lead-lined containers for concentrated and diluted HF have been practically abandoned in Germany (to save imported metals). Rubber-lined steel vessels, especially those lined with hard rubber, are widely used, as rubber adheres firmly and withstands heat. The outer surface must be coated with an acid-resisting lacquer. M.H.

Electric resistance of enamels. V. *Emailwaren-Ind.*, **17** [45–46] 117–18 (1940).—Some enamels have good insulating properties and can be used for coating electrical apparatus, especially where heat is generated. V. gives the results of the work of A. E. Badger and J. F. White (*Jour.*

Amer. Ceram. Soc., **23** [9] 271–74 (1940)) on the effect of different constituents of glass on the electric conductivity. M.V.C.

Enamels with little or no borax content. ANON. *Glashütte*, **70** [48] 621–22 (1940).—If B_2O_3 is omitted from the enamel batch, substitutes which keep the exact molecular unity of the formula must be added so that the properties of the enamel will not be changed. Low fusibility is difficult to obtain in enamels with borax substitutes; luster is less difficult to achieve. The property of B_2O_3 which promotes the conversion of the raw materials and the formation of different compounds and leads to the formation of the undercooled liquid is very difficult to obtain with borax substitutes. The solving action of B_2O_3 on the surface oxides of the metal objects to be enameled (adherence) and the favorable effect of B_2O_3 on the adherence of one layer of enamel to the other are also difficult to obtain. B_2O_3 also aids those chemical reactions which take place during smelting and which are still not fully understood. For these reasons, a small amount of B_2O_3 should be retained in the batch if possible; if B_2O_3 is not available, it must be replaced by substitutes and eutectics which have low fusibility and the other necessary properties. To prevent the occurrence of an unknown chemical transposition of components, these substitutes are first smelted and added as raw material to the batch. The procedure is as follows: The constitutional formula is calculated, the B_2O_3 is taken out, and several components are substituted which have an easily fusible eutectic (divisible by the molecular weight), yield whole numbers, and do not change the expansion of the original enamel. From this new formula, a homogeneous body (double silicate) is made. An example is given which shows how a formula can be so altered; the batch composition and chemical analyses of two enamels are given, and the formulas for replacing the B_2O_3 are worked out. The composition and analysis of the resulting batches are tabulated. M.V.C.

Estimation of hydrogen in steel and other metals. W. C. NEWELL. *Jour. Iron & Steel Inst.* [London], **141** [1] 243–62 (1940).—N. describes a new method for the quantitative estimation of the hydrogen content of metals (especially steel). The theoretical basis of this vacuum-heating method is discussed. Details of the apparatus are shown. The combination of an externally controlled mercury lift and electromagnetic rams makes possible the consecutive estimation of a number of samples without breaking the vacuum of the system. The rate of evolution of hydrogen from steel at various temperatures was studied, and it was confirmed that the amount of hydrogen given off by this method is the same as that given off by the vacuum-fusion method. The vacuum-heating method is ten times more accurate than the former method. A discussion is included. V.D.F.

Factors affecting sagging tests on enameling iron. J. E. SAMS, WILLIAM MCGOHAN, AND J. J. CANFIELD. *Jour. Amer. Ceram. Soc.*, **24** [4] 137–40 (1941).—8 figures, 3 references.

Oxygen–hydrogen–molten iron system. HENRY LEPP. *Jour. Iron & Steel Inst.* [London], **141** [1] 329–39 (1940).—On the basis of previously published data, L. develops an expression for the equilibrium constant, K, of the reversible reaction $2FeO_{\text{in iron}} + 2FeH_{\text{in iron}} + H_{2\,\text{gas}} \rightleftarrows 4Fe_{\text{molten}} + 2H_2O_{\text{gas}}$. K is represented by the equation $\log K = 23{,}586.82/T - 7.5526$. A discussion is included. V.D.F.

Tests on the manufacture of a black enamel without boric acid. VIELHABER. *Emailwaren-Ind.*, **17** [43–44] 113–14 (1940).—The addition of 1% pyrolusite to the mill will produce a very good black enamel, and it is not necessary to prepare in advance an enamel with coloring substances in addition to those ordinarily used. This is a definite advantage for the industry, as the same enamel can be used for both black and brown enamel. V. describes experiments made with black enamels in which water glass replaced part of the SiO_2 and tabulates the compositions of the batches for these enamels. M.V.C.

PATENTS

Enamel firing furnace with continuous charging. CARL THIEL. Ger. 688,669, Feb. 8, 1940 (June 10, 1936); VI/48*c*. 7; addition to Ger. 656,618 (*Ceram. Abs.*, **17** [10] 325 (1938)). D.A.B.

Enameling metallic articles. KARL FRANK (I. G. Farbenind. A.-G.). Ger. 681,715 and 681,716, Sept. 7, 1939 (May 3, 1937); VI/48*c*. 1; addition to Ger. 678,450 (*Ceram. Abs.*, **19** [2] 41 (1940)).—The ground frit is first applied to the metal surface without a water-glass binding agent but with other suitable inorganic or organic binding agents; the water glass is then sprayed on, and an additional substance producing rapid hardening is likewise applied. After hardening of the porous base frit, deposition of the metal takes place. The base frit is treated with solutions containing cations which react with the anions of the metal salt solutions employed for galvanic deposition of metal through the pores of the base frit. The basic layer with the deposited metal is stable at temperatures necessary for enamel layers applied in later stages of the process. D.A.B.

Producing nondiscoloring enamels in the unturbid state. VEREINIGTE CHEMISCHE FABRIKEN KREIDL, HELLER & CO. NFG. Ger. 682,668, Sept. 28, 1939 (Nov. 9, 1936); VI/48*c*. 2.01.—Compounds of metals such as iron, uranium, cerium, antimony, and arsenic (alone or in mixture), especially of oxides or their compounds, are added to the enamel mass or enamel raw materials to avoid the discoloration of enamels when they are being fused onto metal. The enamel is neither colored nor turbidified upon the addition of the above materials, and they prevent discoloration caused by organic materials. D.A.B.

Producing white turbidified enamels, glazes, or glass flux. ADOLF DIETZEL AND RICHARD BONCKE (Kaiser-Wilhelm Institut für Silikatforschung). Ger. 688,787, Feb. 15, 1940 (March 4, 1938); VI/48*c*. 2.02.—White turbidified enamels, glazes, or glass fluxes are produced by the addition of titanium dioxide to the batch which has an alumina content of 12% or more. D.A.B.

Glass

Acid or chemical polishing of glass. V. YA. LOKSHIN. *Stekolnaya Prom.*, **15** [3] 11–15 (1939).—L. discusses the effect of HF and H_2SO_4 solutions used in polishing glassware on the basis of experiments. The results are tabulated. M.V.C.

Change of ultraviolet transparency of glass with temperature. WILLIAM J. ARROL. *Nature*, **145** [3683] 861 (1940).—The transmission of ultraviolet light by glass in the region of 3000 a.u. has long been known to be reduced when the glass is exposed to light and to be restored when the glass is heated to 250° to 300°C. Slow restoration also takes place when the glass is kept in the dark. A. examined another effect in which the absorption coefficients of glasses vary appreciably with temperature in the region of wave length close to the ultraviolet limit of transparency of the glass. The effect is immediately reversible; over the range 10° to 50°C., the relation absorption coefficient-temperature is linear, and in all cases absorption coefficient increases with increase in temperature. The experimental conditions are described, and the percentage variations are given for a number of English glasses. The percentage variation per °C. for photographic plate glass is 0.66 at 3300 a.u. From these results, A. concludes that, in work involving absorption of ultraviolet by glass filters, it is necessary to maintain filter temperatures constant to about 1°C. for reasonable accuracy. He believes that more than one substance in the glass contributes to the effect. J.L.G.

Durability of optical glass. FRANK L. JONES. *Jour. Amer. Ceram. Soc.*, **24** [4] 119–22 (1941).—Eight references.

Economical pot and tank furnaces. E. S. *Glashütte*, **70** [47] 610 (1940).—Tank furnaces are more efficient than pot furnaces in cases where one kind of glass is to be smelted in large quantities. Where smaller quantities of several kinds of glass are to be smelted, the pot furnace must be employed; the technique of firing pot furnaces has progressed to such an extent that the economy in fuel consumption formerly achieved only in tank furnaces can be obtained. For smelting and cooling 1 kgm. of medium hard glass in a medium-sized pot furnace the following fuel consumption is considered good: wood 1.2 kgm., brown coal 0.8 kgm., briquettes 0.8 kgm., and mineral coal 0.6 kgm. These values were obtained by S. in the simultaneous manufacture of crystal, medicine, colored, and bottle glasses. In larger furnaces with large pots the fuel consumption is much lower. In each case these excellent results were made possible only by rational heat economy; this is difficult to obtain because the newest improvements in furnaces, heat conduits, recuperators, burners, secondary furnaces, etc., must be used and adequate technical knowledge and long experience are necessary. M.V.C.

Effect of composition and thermal history on dielectric constants of soda-borosilicate glasses. J. M. HUMPHRYS AND W. R. MORGAN. *Jour. Amer. Ceram. Soc.*, **24** [4] 123–30 (1941).—Eleven figures, 20 references.

Glass for air-raid precaution. ANON. *Glass*, **17** [2] 52 (1940).—The Home Office Air-Raid Precautions Dept. has issued specifications for glass brick, glass panels, toughened glass lenses, and solid lenses. These materials may be used in air-raid shelters without the use of shutters or screen walls. See *Ceram. Abs.*, **19** [5] 110 (1940). B.C.R.

Glass chlorination equipment. T. J. THOMPSON AND CAMPBELL RUTLEDGE, JR. *Ind. Eng. Chem.*, **33** [2] 156–57 (1941).—Progress in the commercial application of chlorination processes has been substantially contingent upon the development of construction materials suitable for withstanding the severe corrosion of such operations. Among the many construction materials which have attained commercial importance, glass has proved to be particularly serviceable for the handling of chlorine, bromine, and their many compounds. Borosilicate glass with its low thermal expansion and marked chemical stability provides a material uniquely resistant, over a wide temperature range, to the destructive effects of powerful oxidizing agents, hydrochloric acid, and hydrobromic acid. In the form of flanged piping, socket piping, heat-exchanger tubing, fractionating columns, and centrifugal pumps of standard design, such glassware is well suited to the fabrication of highly useful equipment and accessories for chlorine and bromine processing. Illustrated. F.G.H.

Glass fracture with high-speed photography. H. E. EDGERTON AND F. E. BARSTOW. *Jour. Amer. Ceram. Soc.*, **24** [4] 131–37 (1941).—Fourteen figures, 2 references.

Glass industry in former Poland. KURT CZULIUS. *Glashütte*, **70** [47] 609–10 (1940).—Former Poland possessed about 60 to 65 active glass factories; these consisted mostly of small firms which operated only 6 to 8 months out of the year and some joint stock companies. Technical facilities were for the most part outmoded, and in the smaller plants they were primitive. Not only was expert technical knowledge lacking, but there was also a chronic money shortage. The majority of factories operated at a loss. Overproduction, caused by the appallingly low buying power of the Polish people, led to a suicidal price-cutting policy. Raw materials were held up, quality deteriorated, and communistic workers' organizations fought with the capitalists. M.V.C.

Manufacture of mirror glass 200 years ago. FRITZ HANSEN. *Diamant*, **62** [5–6] 34–35 (1940).—H. describes the tedious and painstaking process of making plate glass for mirrors from blown glass in 1745. Details are given of the grinding and polishing processes during which the glass plate was held on large tables by means of gypsum. Old photographs are reproduced. M.H.

Measuring the thickness of glassware. HANS FREYTAG. *Glashütte*, **70** [40] 521–24 (1940).—There are three methods of measuring the thickness of glass: (1) mechanical, (2) optical, and (3) mathematical. The mechanical and optical methods can be used for measuring sheet glass and hollow glassware; the mathematical method is used only for hollow glassware. The three methods and the instruments required in each case are briefly described and illustrated. (1) Among instruments used for mechanical measurements, the slide gauge and especially the measuring meter give good results in measuring the thickness of flat glasses. (2) The optical method, which is based on the property of glass of transmitting and reflecting light, is used for installed sheet glass. The simplest type of instrument for optical measurement can be made out of a carton, and its principle is illustrated by a diagram. The microscope is used when it is necessary to determine the thickness of glass very exactly for chemical or physical radiation tests (exact determination of the intensity of a light from an inclosed source of radiation). The methods of S. Czapski, B. Walter, and E. Leitz and the Zeiss optometer are described. Simpler and less exact instruments can be used in industrial technique; the principles of the Görz instrument (no longer on the market) and the Plagwitz apparatus are given. The latter is economical only for large-scale industry. (3) The mathematical processes are based on formulas derived empirically or from geometrical determinations obtained by measurements of the form of the hollow glass object; only those values which can easily be determined by a simple mechanical method, e.g., with the sliding gauge, etc., are used. The empirical formulas give only approximate results, while the geometrical formulas using direct measurements yield good mean values. Formulas for determining the thickness of the walls of an incandescent lamp bulb and of a prismatic flask with square cross section are given and explained. M.V.C.

Pitchstone and slag in the glass batch. L. SPRINGER. *Glashütte*, **70** [50] 645–46 (1940).—S. discusses the efficacy of using pitchstone and soda slag in the glass batch. M.V.C.

Requirements for the principal glass raw materials and their structure: II, Minium. ANON. *Glashütte*, **70** [49] 633–34 (1940).—(1) Mechanical structure: The volume weight of minium varies greatly. The finely powdered form is desirable because it aids dispersion in the batch and reacts better and more quickly with the other constituents. The grain size is important; a microscopic examination of a sample in suspension in a neutral solution (methyl alcohol) on a slide should be made to determine any irregularity in the grain size, which contributes to the danger of loss by the scattering of dust. (2) Chemical state: The principal requirement of minium is that it contain no metallic lead. The iron content must be very low, under 0.004% Fe or 0.0057% Fe_2O_3 or, for ordinary glass, 0.01 to 0.02% Fe_2O_3. A minimum of 26 to 32.5% lead superoxide and a maximum moisture content of 1.5% are required. The presence of nickel and copper even in small quantities is injurious. For Part I see *Ceram. Abs.*, **19** [10] 233 (1940). M.V.C.

Speed of crystallization of some silicate glasses as a function of viscosity. A. LEONT'EVA. *Acta Physicochim. U.R.S.S.*, **13**, 423–28 (1940).—L. attempts to determine an equation to represent the linear speed of crystallization of silicate glasses in the region of supercooling. This must be inversely proportional to the viscosity. Experimental data obtained by others for the system Na_2O–CaO–SiO_2 were used. The equation is $v = K/\eta + K_0 \log \eta$, where v is linear speed in microns per min., η is viscosity in poises, and K and K_0 are constants. This equation gives a curve which fits the experimental data closely. W.D.F.

System sodium disilicate–barium disilicate. K. T. GREENE AND W. R. MORGAN. *Jour. Amer. Ceram. Soc.*, **24** [4] 111–16 (1941).—Three diagrams, 14 references.

Testing the chemical resistance of ampoules. O. KNAPP. *Glass Ind.*, **22** [1] 17–19, 32 (1941).—If excessive amounts of alkalis are extracted from glasses containing medicinal solutions, they may cause disagreeable and dangerous

changes in the contents. No standardized international test exists for the evaluation of ampoule glass. The tests for nine different countries are briefly described and are divided into two groups measuring the chemical durability of whole and of crushed ampoules. The advantages and disadvantages of each type are listed. K. proposes this method: To a 250-ml. flask made of resistant glass and boiled out carefully, methyl red neutral distilled water is added, and the flask is sealed. The glass or ampoule to be tested is crushed and sieved on an 0.3 and an 0.5 mm. sieve (American Taylor Nos. 48 and 32, British IMM Nos. 36 and 25, DIN 1171 Nos. 12 and 20). The grains within both sieves are washed thoroughly with alcohol and then dried; 5 gm. of the prepared grains are added to a resistant flask containing 100 ml. methyl red neutral distilled water and 0.4 ml. *N*/100 hydrochloric or sulfuric acid. The flask is heated in a boiling water bath for ½ hr. The level of the liquid in the flask should be lower than the level of the bath. The contents are cooled and back titrated with *N*/100 NaOH. Results are expressed as 0.40 ml. minus ml. NaOH. A.P.

Vitreous silica equipment in chlorination processes. WILLIAM W. WINSHIP. *Ind. Eng. Chem.*, **33** [2] 143–48 (1941).—Vitreous silica has been used and specified by many workers in the field of organic (chlorination) and inorganic (chloridizing) reactions with chlorine. Indifference to severe temperature conditions, to chlorine even in its nascent condition, and to chlorinated organic compounds and most metallic chlorides, together with noncatalytic properties and, in the transparent variety, high transmission of actinic light, provides a chemical engineering material valuable for reactor construction and for equipment required in hydrogen chloride, hydrochloric acid, and chloride recovery. An extension of the use of fused silica and quartz glass on an industrial scale is suggested along lines of application which have already proved their value. Illustrated. F.G.H.

Working of multiply safety glass. ANON. *Diamant*, **61** [35–36] 315–17 (1939); see *Ceram. Abs.*, **20** [3] 67 (1941). M.H.

X-ray study of lime-phosphate and lime-borate glass. J. BISCOE, A. G. PINCUS, C. S. SMITH, JR., AND B. E. WARREN. *Jour. Amer. Ceram. Soc.*, **24** [4] 116–19 (1941).—Four curves, 5 references.

PATENTS

Apparatus for blowing glass wool. H. C. BATES (Owens-Corning Fiberglas Corp.). U. S. 2,235,352, March 18, 1941 (March 30, 1937).

Apparatus for conditioning molten glass. C. C. KINKER (Owens-Illinois Glass Co.). U. S. 2,234,147, March 4, 1941 (Oct. 7, 1938).

Apparatus for making colored sheet glass. J. H. FOX (Pittsburgh Plate Glass Co.). U. S. 2,233,597, March 4, 1941 (Jan. 6, 1938).

Apparatus for producing hollow glass objects with a mouth difficult to fabricate. KARL A. ZUMPE. Ger. 688,265, Jan. 25, 1940 (Sept. 9, 1938); VI/32*a*. 15.—The parts forming the mouthpiece are provided for in a socket which is independent of the glass-blowing machine and which is attachable to this machine. D.A.B.

Apparatus for tempering glass plates in a horizontal position. PRODUITS VITRIFIÉS DE ST.-CHRISTOPHE S. A. Ger. 685,952, Dec. 7, 1939 (March 6, 1937); VI/32*a*. 30. D.A.B.

Apparatus for tempering glass sheets. PILKINGTON BROS., LTD. Brit. 533,115, Feb. 19, 1941 (Oct. 14, 1938).

Apparatus for turning blown cup-shaped glass vessels. MARTIN FULDA AND HANS BERGER (Vereinigte Lausitzer Glaswerke A.-G.). Ger. 688,963, Feb. 15, 1940 (May 4, 1938); VI/32*a* 7. D.A.B.

Apparatus and method for controlling temperature in lehrs. D. G. MERRILL (Hartford-Empire Co.). U. S. 2,233,629, March 4, 1941 (Sept. 1, 1938).

Apparatus and method for production of fibers from glass, slag, and like meltable materials. FRIEDRICH ROSENGARTH AND FRITZ HAGER (Owens-Corning Fiberglas Corp.). U. S. 2,234,087, March 4, 1941 (Nov. 16, 1931).

Automatic glass-blowing machine. JOHANN MAINZER (Deutsches Verband der Flaschenfabriken G.m.b.H.). Ger. 682,547, Sept. 28, 1939 (Jan. 8, 1937); VI/32*a*. 15. D.A.B.

Building block. E. T. PUTNAM (Libbey-Owens-Ford Glass Co.). U. S. 2,235,114, March 18, 1941 (March 29, 1937).

Building unit. E T. PUTNAM (Libbey-Owens-Ford Glass Co.). U. S. 2,235,115, March 18, 1941 (June 11, 1937).

Carriers for glass plates. AUGUST RAPP (Firma Friedr. Wilh. Giese). Ger. 689,299, Feb. 29, 1940 (March 18, 1938); X/34*b*. 1.04. D.A.B.

Cellular glass and process of manufacture. E. H. HAUX AND W. O. LYTLE (Pittsburgh Plate Glass Co.). U. S. 2,233,608, March 4, 1941 (Dec. 28, 1937).

Coating the interior surface of the envelopes of electric lamps. WESTINGHOUSE ELECTRIC INTERNATIONAL CO. Brit. 532,783, Feb. 12, 1941 (Sept. 29, 1938).

Continuous drawing of an endless glass band. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY. Ger. 682,416, Sept. 28, 1939 (May 25, 1936); VI/32*a*. 23.01. D.A.B.

Decorative glass and method of producing. W. O. LYTLE (Pittsburgh Plate Glass Co.). U. S. 2,233,622, March 4, 1941 (April 14, 1938).

Drawing an endless glass band from glass melt. N. V. HOLLANDSCHE MIJ. VOOR DE VERVAARDIGING VAN GLAS. Ger. 681,570, Sept. 7, 1939 (Sept. 26, 1936); VI/32*a*. 23.01. D.A.B.

Electrically heated glass tank furnace. SOC. ANON. POUR LES APPLICATIONS DE L'ÉLECTRICITÉ AU VERRE. Ger. 688,015, Jan. 18, 1940 (Aug. 14, 1936); VI/32*a*. 4.—At least two electrodes are arranged in the glass melt between the feeding point and the withdrawing point, and the line between the electrodes has a course which is oblique to the direction of flow of the melt and horizontal in reference to the entire width of the furnace. A heating zone is produced by the current lines emanating from the two electrodes; this heating zone lies in the course of the melt and is bound by two lines of current running oblique to the flowing direction of the glass and extends from one lengthwise-running wall of the furnace to the opposite wall. D.A.B.

Equipment for producing hollow glass building blocks. MINOT HOLMES, DAVID JONES, AND HAROLD EASTUS (A.-G. der Gerresheimer Glashüttenwerke vorm. Ferd. Heye). Ger. 688,692, Jan. 8, 1940 (Oct. 19, 1937); VI/32*a*. 24.04.—Equipment is described for the joining together of glass parts, especially of half blocks, to form hollow glass building blocks. D.A.B.

Equipment for rolling glass. HUGO NOWOTNY. Ger. 689,254, Feb. 29, 1940 (Jan. 23, 1939); VI/32*a*. 19. D.A.B.

Eyeglass lens. A. J. ANDERSON AND J. G. WESCOTT (N. P. Benson Optical Co., Inc.). Can. 393,900, Jan. 14, 1941 (Aug. 18, 1939). G.M.H.

Face block for buildings and method of making. E. T. PUTNAM (Libbey-Owens-Ford Glass Co.). U. S. 2,235,113, March 18, 1941 (May 21, 1936).

Fixing filter plates and other parts in vessels made of glass or quartz. GLASFABRIK SOPHIENHÜTTE R. BOCK GES. Brit. 532,137, Jan. 29, 1941 (Sept. 29, 1938).

Glass-bottle machine. C. B. GARWOOD (Carr-Lowrey Glass Co.). U. S. 2,235,103, March 18, 1941 (March 22, 1938).

Glass-fiber products. BRITISH THOMSON-HOUSTON CO., LTD. Brit. 532,596, Feb. 12, 1941 (Sept. 10, 1938).

Glass-to-metal seals. BRITISH THOMSON-HOUSTON CO., LTD. Brit. 532,907, Feb. 12, 1941 (Sept. 23, 1938).

Glass and other pressed or molded prismatic reflectors and their manufacture. H. F. WILSON. Brit. 532,672, Feb. 12, 1941 (July 17, 1939).

Glass sheet bending apparatus. H. J. GALEY (Pittsburgh Plate Glass Co.). Can. 393,969, Jan. 14, 1941 (May 6, 1940; in U. S. July 11, 1939). G.M.H.

Glass skeleton mold. H. J. GALEY (Pittsburgh Plate Glass Co.). Can. 393,970, Jan. 14, 1941 (May 8, 1940; in U. S. Jan. 16, 1940). G.M.H.

Glass stock for electric melting. HENRY SNOW (Owens-Corning Fiberglas Corp.). U. S. 2,233,435, March 4, 1941 (Feb. 26, 1938).—The method of melting glass for use in forming filaments comprises forming glass into substantially spherical shapes and imparting strains therein, feeding the shapes into a furnace, and melting the shapes in the furnace.

Glassware-forming machine. C. R. VINING AND I. C. HAMILTON (Libbey Glass Co.). U. S. 2,235,129, March 18, 1941 (March 20, 1939).

Glass wool. H. V. SMITH (Owens-Corning Fiberglas Corp.). U. S. 2,233,433, March 4, 1941 (Aug. 6, 1936).

Glass-wool insulation for electrical heating resistance. HANS SIEGRIST. Ger. 681,016, Aug. 24, 1939 (May 12, 1937); VIII*c*/21*h*. 2.02. D.A.B.

Glassworking apparatus. CORNING GLASS WORKS. Brit. 532,936, Feb. 12, 1941 (Aug. 12, 1938); divided out of 532,888, "Process . . .," this page.

Grinding of plate glass. N. S. GARBISCH. Brit. 532,779, Feb. 12, 1941 (April 14, 1939).

Grit-coated glass block. R. R. MCGREGOR (Corning Glass Works). U. S. 2,232,465, Feb. 18, 1941 (Aug. 18, 1939).—A glass building block having mortar-bearing faces provided with a coating applied directly to the glass and adherent thereto and having a rough-surfaced coating of granular material superimposed upon and bonded to the block by the first-named coating, the granular material having a hardness not greater than 4.5 on Mohs' scale.

Heat insulation. A. D. SABORSKY (Fiberglas Canada, Ltd.). Can. 394,808, Feb. 25, 1941 (June 30, 1938; in U. S. June 30, 1937). G.M.H.

Heat-resisting glass. BRITISH THOMSON-HOUSTON CO., LTD., AND J. E. STANWORTH. Brit. 533,361, Feb. 26, 1941 (Aug. 10, 1939).

Hollow glass article making apparatus. H. H. BLAU (Corning Glass Works). Can. 394,089, Jan. 21, 1941 (Jan. 28, 1939; in U. S. March 3, 1938). G.M.H.

Laminated glass. H. T. NEHER AND C. F. WOODWARD (Röhm & Haas Co.). U. S. 2,234,829, March 11, 1941 (Sept. 16, 1939).

Laminated safety glass. J. D. RYAN (Libbey-Owens-Ford Glass Co.). U. S. 2,232,806, Feb. 25, 1941 (May 3, 1937).

Lehr. F. G. SCHWALBE. U. S. 2,232,638, Feb. 18, 1941 (Feb. 20, 1939).

Lens-cutting machine. A. M. FLATTEM. U. S. 2,231,994, Feb. 18, 1941 (May 9, 1940).

Machine for grinding hollow spaces. DEUTSCHE WAFFEN- UND MUNITIONSFABRIKEN A.-G. Ger. 688,672, Feb. 8, 1940 (March 30, 1935); XII/67*a*. 9. D.A.B.

Making glass bulbs. BRITISH THOMSON-HOUSTON CO., LTD. Brit. 533,473, Feb. 26, 1941 (Nov. 9, 1938).

Manufacture comprising foliated glass and process of producing. P. E. HARTH. U. S. 2,233,259, Feb. 25, 1941 (Feb. 7, 1934).

Manufacture of glassware and product produced thereby. CORNING GLASS WORKS. Brit. 533,053, Feb. 19, 1941 (Nov. 4, 1938); addition to 442,526.

Manufacture of ruby glass. F. J. DOBROVOLNY AND C. H. LEMKE (E. I. du Pont de Nemours & Co.). U. S. 2,233,343, Feb. 25, 1941 (March 10, 1939).—A ruby glass containing copper as red colorant and an amount of bismuth equivalent to an amount of Bi_2O_3 which is not more than one half of the weight of metallic copper present and which does not exceed about 0.3% by weight of Bi_2O_3.

Manufacturing cellular glass. R. A. MILLER AND W. O. LYTLE (Pittsburgh Plate Glass Co.). U. S. 2,233,631, March 4, 1941 (Dec. 28, 1937).

Method and apparatus for forming glassware. L. MELLERSH-JACKSON (Hartford-Empire Co.). Brit. 532,778, Feb. 12, 1941 (Sept. 19, 1939).

Method and apparatus for making glass. W. S. RENDALL (Crown Cork & Seal Co., Inc.). U. S. 2,234,605, March 11, 1941 (Nov. 13, 1936).

Method and apparatus for producing glass filaments. ADOLF DIETZEL. U. S. 2,234,521, March 11, 1941 (Feb. 23, 1939).

Method and apparatus for the production of tapes or strips of glass silk. VERSIL, LTD., AND S. PALMER. Brit. 532,456, Feb. 5, 1941 (July 21, 1939).

Method and means for manufacturing relatively thin hollow glass articles. UNITED GLASS BOTTLE MANUFACTURERS, LTD., AND E. P. DORMAN. Brit. 533,252, Feb. 19, 1941 (Oct. 23, 1939).

Mold operating in glassworking. CORNING GLASS WORKS. Brit. 532,934, Feb. 12, 1941 (Aug. 12, 1938); divided out of 532,888, "Process . . .," this page.

Nonglare safety glass. E. L. FIX (Pittsburgh Plate Glass Co.). U. S. 2,233,941, March 4, 1941 (June 23, 1936).

Preheating moldable materials. S. T. MORELAND (Owens-Illinois Glass Co.). U. S. 2,235,324, March 18, 1941 (Oct. 14, 1937).

Preparing nodular or coherent masses from finely divided siliceous materials in the manufacture of siliceous bodies and providing a glass-batch material. A. H. STEVENS (N. S. Garbisch). Brit. 532,061, Jan. 29, 1941 (Aug. 15, 1939).

Process and apparatus for working glass. CORNING GLASS WORKS. Brit. 532,888, Feb. 12, 1941 (Aug. 12, 1938).

Producing articles of silica. FRANZ SKAUPY AND GUSTAV J. WEISSENBERG. Ger. 682,719, Oct. 5, 1939 (Dec. 19, 1936); VI/32*a*. 35.—Objects of silica or quartz powder are sintered gradually and melted. The objects are heated to a temperature sufficient for finishing, at which no cristobalite formation will occur; they are then heated until the individual quartz objects become completely vitrified. The objects are heated at 1800°C. for a short time only to prevent the harmful formation of cristobalite. **Ger. 688,782**, Feb. 15, 1940 (July 21, 1937); VI/32*a*. 35; addition to Ger. 682,719.—To produce a vitreous surface, the articles are heated for a short time at a temperature which is considerably higher than is necessary for the sintering of the silica particles. An uninterrupted heating is desirable. D.A.B.

Producing drop bottles. CARL SCHNUERLE. Ger. 688,617, Feb. 8, 1940 (March 8, 1937); VI/32*a*. 15; addition to Ger. 658,752, March 24, 1938 (Nov. 6, 1933).—A method is given for producing the constriction in the neck of the drop bottle. D.A.B.

Producing hollow glass objects having an opening on one side. FRANZ GASCHLER. Ger. 681,230, Aug. 31, 1939 (Nov. 2, 1937); VI/32*a*. 24.04. D.A.B.

Producing hollow glass objects with reinforced bases from glass tubes. JAKOB DICHTER. Ger. 689,280, Feb. 29, 1940 (Dec. 16, 1935); VI/32*a*. 27; addition to Ger. 685,193 (*Ceram. Abs.*, **19** [11] 257 (1940)). D.A.B.

Production of crimped glass fibers. ALGEMEENE KUNSTVEZEL MIJ. N. V. Brit. 533,032, Feb. 19, 1941 (Aug. 4, 1938).

Production of mineral wool bats. ALGEMEENE KUNSTVEZEL MIJ. N. V. Brit. 532,528, Feb. 5, 1941 (July 26, 1938).

Production of very thin, flexible sheets of fused quartz. FRANZ SKAUPY AND GUSTAV J. WEISSENBERG. Ger. 682,606, Sept. 28, 1939 (April 27, 1937); VI/32*a*. 35.—Fused quartz or glasslike oxides having a high fusing temperature are fashioned into very thin, flexible sheets of any width by producing a feltlike mass of threads or short fiber material from the quartz or the glassforming oxides. A binding agent is employed to form a preliminary thin sheet, and the sheet thus obtained is dried. Afterward, the individual threads of the sheet are fused together by heating and by application of pressure by means of rollers, etc., so that a pliable sheet results. D.A.B.

Purification of silica sands. F. W. ADAMS (Rockware Glass Syndicate, Ltd.). U. S. 2,233,155, Feb. 25, 1941 (July 8, 1939).

Safety device for glass-blowing machine. FRANK O'NEILL. Ger. 681,756, Sept. 7, 1939 (Aug. 26, 1936); VI/32*a*. 15. D.A.B.

Sealing glass tubes onto glass vessels. EGYESÜLT IZZÓLÁMPA ÉS VILLAMOSSÁGI RESZVENYTARSASAG. Brit. 533,063, Feb. 19, 1941 (Oct. 4, 1938).

Sealing tungsten objects into glass. PHILIPS LAMPS, LTD. Brit. 532,451, Feb. 5, 1941 (July 13, 1938).

Separating glass articles from a ribbon of glass. G. L. CURRY AND A. N. SMITH (Corning Glass Works). U. S. 2,235,359, March 18, 1941 (April 14, 1939).

Shear apparatus for molten glass. CORNING GLASS WORKS. Brit. 532,935, Feb. 12, 1941 (Aug. 12, 1938); divided out of 532,888, "Process. . .," this issue, p. 116.

Transfer mechanism for glass articles. A. F. TREMBLAY (Kent-Owens Machine Co.). U. S. 2,232,285, Feb. 18, 1941 (June 10, 1938).

Varicolored glass articles and process of making. CORNING GLASS WORKS. Brit. 533,461, Feb. 26, 1941 (Dec. 5, 1938).

Structural Clay Products

Relation of water absorption and strength of brick to abrasive resistance. J. W. MCBURNEY, R. H. BRINK, AND A. R. EBERLE. *Proc. Amer. Soc. Testing Materials*, **40**, 1143–53 (1940).—The Kessler portable abrasion tester was used to determine the comparative abrasive resistance of approximately fifty clay, fire-clay, and shale brick of known strength and absorption. These brick were selected to represent the maximum range in properties commercially available. From the data obtained, the following conclusions were drawn: (1) The abrasive resistance of brick increases with their compressive strength. Plotting abrasive loss against compressive strength gave points which fall in a band of hyperbolic form. (2) The abrasive resistance of brick decreases as water absorption increases. This relation is rather definite for brick with an absorption of less than 10% during 5 hr.'s boiling. With an absorption above 10% the scatter in results becomes very large. (3) Under the conditions of test, abrasive losses determined on brick saturated with water were not significantly greater than those determined on the same brick tested dry.
R.A.H.

PATENTS

Apparatus for producing hollow brick closed on all sides on a wire-cutting press. FRIEDRICH K. REISSMANN. Ger. 682,751, Oct. 5, 1939 (Jan. 22, 1937); VI/80*a*. 43.10; addition to Ger. 646,809. D.A.B.

End-grooving apparatus for hollow tile. J. D. THOMPSON. U. S. 2,232,283, Feb. 18, 1941 (March 28, 1939).

Form for producing brick, etc., which have openings on only one side. FRITZ SCHMELING. Ger. 689,174, Feb. 22, 1940 (March 28, 1936); VI/80*a*. 43.10.—A design is given for the hand-operated pressure stamp for producing brick having openings on only one side. D.A.B.

Multihole brick. ARTHUR SCHUBERT. Ger. 685,982, Dec. 7, 1939 (May 7, 1935); V/37*b*. 1.01. D.A.B.

Porous clayware. H. S. COLTON (H. S. Colton, M. J. Rentschler, and J. A. Weeks). U. S. 2,231,989, Feb. 18, 1941 (June 15, 1938).—The method of making porous clayware comprises forming a joint precipitate of calcium sulfate and ferrous hydroxide in the proportions of approximately 60 and 40%, respectively, mixing the precipitate with clay, the mixture containing a large percentage of water while remaining moldable, the proportions by weight of the clay and colloidal material being approximately 1:2, forming a plastic mixture of these constituents into articles of desired shape, and firing the articles, whereby the resulting ware contains pores of microscopic size and has a relatively low specific gravity.

Producing hollow clay tile. E. C. GAERTNER (Reconstruction Finance Corp.). U. S. 2,235,291, March 18, 1941 (April 3, 1939).

Refractories

American soaking-pit and reheating-furnace design and practice. FREDERICK M. GILLIES AND EDWIN D. MARTIN. *Jour. Iron & Steel Inst.* [London], **138** [2] 319–48 (1938). **Discussion.** J. B. DEAKIN ET AL. *Ibid.*, **139** [1] 527–34 (1939). V.D.F.

Compositions of different refractory products. PIERRE RENAULT. *Rev. Matériaux Construction Trav. Publics*, No. 351, pp. 145–48B (1938); No. 352, pp. 7–9B; No. 353, pp. 15–18B; No. 354, pp. 28–32B; No. 355, pp. 40–42B; No. 356, pp. 53–55B; No. 357, pp. 65–66B (1939).—Examples of compositions of different types of refractories used in the ceramic and other industries are tabulated. As some of these masses have been used for the last 50 years, conclusions may be drawn concerning the choice of available raw materials, their relative properties, the action of each constituent, and whether they can be used in the various methods of manufacturing. R.'s purpose is to furnish a guide for manufacturers and buyers and to present compositions which are perfectly satisfactory for certain conditions. Formulas show the multiplicity of problems which arise during the manufacture of refractories and which must be solved. Data are given on the composition of (1) different types of refractory brick, (2) molded saggers, (3) cast saggers, (4) supports and accessories used for charging, (5) fire guards, slabs for protective walls, etc., (6) pegs or rods for suspending the charge, (7) refractory mortars, (8) thin mortars, and (9) luting.
M.V.C.

Design and operation of the open-hearth furnace for melting malleable cast iron. G. R. SHOTTON. *Proc. Inst. Brit. Foundrymen*, **32** [673] 183–92 (1938–39).—S. deals with the life and maintenance costs of refractory materials. He states that the side walls and crown of the furnace may last for 12 to 24 months, while the port blocks must be rebuilt at intervals of 4 to 6 months. The total maintenance cost for the refractories of a furnace of 8-ton capacity, calculated over a period of three years, was 1s 11d per ton of metal melted. R.H.

Development of the open-hearth steelmaking processes in recent years in the United States. L. F. REINARTZ. *Jour. Iron & Steel Inst.* [London], **138** [2] 349–95 (1938). **Discussion.** R. PERCIVAL SMITH ET AL. *Ibid.*, **139** [1] 479–94 (1939). V.D.F.

Discussion on "First Report on Refractory Materials." T. SWINDEN ET AL. *Jour. Iron & Steel Inst.* [London], **139** [1] 651–66 (1939); see abstracts from *Iron & Steel Inst., Special Rept.*, No. 26 (1939) in *Ceram. Abs.*, **19** [2] 46, 47, 48; [5] 115, 116, 117; [6] 141, 142; [7] 163 (1940). V.D.F.

Evaluation of chrome ores for the manufacture of refractories. T. SCHAUER. *Tonind.-Ztg.*, **63** [61] 701–702; [62] 724–25 (1939).—The basic material of chrome ore (chromite) has a melting point of 2180°C. Natural deposits of chromite are always mixed with magnesia, alumina, and silica. The refractory industry uses chrome ores containing 60 to 70% chromite. Among the components, silica is the most important; it acts as a cement, thus preventing disintegration. Too much silica decreases the refractoriness under load. Tests on the solubility of chrome ores in mineral acids show that their essential constituents are chromite ($FeO \cdot Cr_2O_3$), forsterite ($2MgO \cdot SiO_2$), and spinel ($MgO \cdot Al_2O_3$). Assuming that the system MgO–Al_2O_3–SiO_2 exists in the form of $2MgO \cdot SiO_2$ and $MgO \cdot Al_2O_3$, the equation $\frac{\%MgO - \frac{\%Al_2O_3}{2.67}}{\%SiO_2} = 1.38$ furnishes a thumb rule for the evaluation of chrome ores:

a quotient higher than 1.38 indicates high refractoriness and resistance to temperature changes; a quotient less than 1.38 indicates lowered refractoriness and resistance to temperature changes; and a quotient larger than 5 indicates lack of silica resulting in reduced strength. Investigations on chrome-magnesite brick showed that chrome ores containing up to 10% SiO_2 are not objectionable; firing in the presence of magnesite results in the formation of forsterite, preventing the formation of $2FeO \cdot SiO_2$ and free SiO_2. Siemensite, a synthetic chromite made in Germany, has exactly the same mineralogical structure and properties as natural chrome ore. F.E.S.

Examination of samples of silica brickwork taken from a vertical retort and showing evidence of pronounced alkali attack. F. H. Clews, W. Hugill, and A. T. Green. *Bull. Brit. Refrac. Research Assn.*, No. 48 (Oct., 1938); reprinted in *Trans. Brit. Ceram. Soc.*, **39** [11] 337–44 (1940); see *Ceram. Abs.*, **18** [8] 213 (1939). R.A.H.

Furnace for determining thermal resistance. V. A. Lebedev. *Ogneupory*, **7** [7] 495–500 (1939).—L. describes the construction of a simple electric furnace for testing the thermal resistance of grog products. See *Ceram. Abs.*, **20** [1] 23 (1941). M.V.C.

General regularities for the heat conductivity of various materials and aggregate conditions. A. Eucken. *Forsch. Gebiete Ingenieurw.*, **11** [1] 6–20 (1940).—E. treats the problem of heat exchange theoretically and develops formulas for calculating the heat-conductivity values for gases, liquids, solids, and heterogeneous substances. He concludes that the heat conductivity for any gas can be calculated exactly to within a few per cent if its viscosity and specific heat are known. The heat conductivities of many chemically and physically related liquids usually differ little; thus the conductivity of an unknown liquid can be estimated from that of another liquid with an accuracy of 5 to 10%. The exact calculation of the heat conductivity of nonmetallic solid substances, e.g., of ceramic (refractory) materials, from other physical quantities is not yet possible. Although the porosity could be taken into account, the mass consists of crystal grains and a glassy part. As these differ considerably in their heat conductivity, the latter depends essentially on the ratio glass to crystalline substances and on their distribution and only slightly on chemical composition. The heat conductivity can, in principle, be determined by the formula $\frac{1}{\lambda_m} = \frac{1}{\lambda_s} + \frac{\gamma_p}{3\lambda_p}$, where λ_s is the heat conductivity of the coherent mass, γ_p is the volume of all pores (in %), and λ_p is the heat conductivity of the pores; generally, a direct determination is more practical and is usually possible though tedious. The heat conductivity of metals can be determined from the electric conductivity by the Wiedemann-Franz-Lorenz law; a slight modification is necessary for alloys. M.H.

Manufacture of chromite retorts. S. A. Vigdorov. *Ogneupory*, **5** [9] 657–58 (1937).—V. discusses the advantages of chromite retorts over aluminous retorts. Laboratory tests showed the possibility of manufacturing such retorts. M.V.C.

Mineralogy of lime refractories. A. T. Kleĭnberg. *Ogneupory*, **6** [10] 1547–51 (1938).—Dicalcium ferrite is formed during the firing of batches of CaO and Fe_2O_3 in an oxidizing medium. In a reducing atmosphere iron oxide reduces into metallic iron. Reactions in a batch of $m(3CaO + SiO_2) + n(2CaO + Fe_2O_3)$ fired to 1380° to 1700° produce a considerable quantity of unstable β-$2CaO \cdot SiO_2$. When firing a similar batch in oxidizing atmosphere, dicalcium ferrite is formed in addition to dicalcium and tricalcium silicates. M.V.C.

Quality requirements of refractories in the production of special steels. A. T. Zhak. *Ogneupory*, **7** [5] 312–30 (1939).—The properties of refractories used in the production of different types of steels are enumerated. M.V.C.

Refractory brick, saggers, and furnace parts. Pierre Renault. *Rev. Matériaux Construction Trav. Publics*, No. 349, pp. 121–26B (1938).—R. gives data on the manufacture of refractory brick, saggers, and other refractory and silica products. Compositions are tabulated. The questions of shrinkage, plasticity and cohesion, refractoriness, expansion, resistivity, shaping, preparation of mixes, and percentage of water are discussed. M.V.C.

Refractory concrete. A. Möser. *Tonind.-Ztg.*, **63** [67] 762–63; [68] 775–76; [69] 789–91 (1939).—To increase the cold strength of refractory masses, various admixtures such as molasses, waste sulfite liquor, and water glass have been used; only the latter provides lasting increase of strength, but it decreases refractoriness and lowers the softening point. Aluminous cement or *ciment fondu*, made by fusing lime and bauxite together in an electric furnace, is a hydraulic binder having refractory properties. Aggregates to be used with aluminous cement are fired fire clay, crushed firebrick, or dead-burned materials of high alumina content; siliceous aggregates are unsuitable. Mixtures containing 33, 25, and 20% aluminous cement show changes of strength on heating as follows: at 100°C. strength decreases; at 200°C. it increases; from 600° to 1000°C. it decreases; between 1000° and 1300°C. the hydraulic bond changes to become a ceramic bond; at 500°C. the blue-gray color becomes dark brown; at 800°C., when dehydration is completed, the color lightens again. The essential characteristic of aluminous cement is that, after it is fired at 1200° to 1300°C. and dipped into water, rehydration and increase of strength take place. According to M. Lepingle, the composition of aluminous cement is 10 SiO_2, 40 Al_2O_3, and 50% CaO. When aggregates containing 20% Al_2O_3 are used, ternary eutectics with melting points from 1165° to 1380°C. are formed; with aggregates of 40 to 100% Al_2O_3, the melting points of the eutectics lie between 1335° and 1505°C. The eutectic Al_2O_3–$(Al_2O_3 \cdot 2CaO \cdot SiO_2)$–$CaO \cdot Al_2O_3$, having a melting point of 1505°C., can be formed with an aggregate of 40% Al_2O_3 only if the concrete contains 14.3 to 16.6% of the aggregate; with an aggregate of 70% Al_2O_3, the eutectic can be formed when 22.2 to 35.9% of this aggregate is added. If pure alumina is used as an aggregate, the eutectic is formed in all compositions containing more than 25.8% of the aggregate. Aluminous cement suitable for refractory concrete must have a high Al_2O_3 content, must contain no free lime after setting, must have no change in structure of Ca aluminates during dehydration, and must have no impurities which lower the melting point. Correct grading of the aggregate is important. Contrary to requirements for structural concrete, refractory aggregates must have a large amount of fines and dust. The equation of Bolomey, $y = A + (100 - A) \times \sqrt{\frac{d}{D}}$, has been suggested for determining the proportion of particle sizes. In this formula, y = the passage through the sieve, d = the particle size in millimeters of the group to be determined, D = the size of the biggest particles in millimeters, and A is a constant between 14 and 30. With $A = 25$, the grading is 14% 15 to 10 mm., 18% 10 to 5 mm., 16% 5 to 2 mm., 14% 2 to 0.5 mm., and 38% less than 0.5 mm.; aluminous cement 15%. Before mixing, the aggregate should be soaked so that it will not absorb water necessary for hydration. M. gives results of tests by Chadeyron (*Ceram. Abs.*, **17** [2] 72 (1938)) on the refractoriness under a load of 3.52 kgm. per sq. cm. Lightweight refractory concrete for insulating purposes has been developed by A. Rolzen (*Ceram. Abs.*, **17** [6] 222 (1938)). One method uses soap foam as an admixture to a slip of 25 parts aluminous cement and 75 parts filler. The amount of water added was 25 to 30% of the dry weight of the ingredients. The soap solution contained 0.25% glue and 0.25% colophony soap; 0.6 to 1 volume part of foam was added to 1 volume part of the slip. The mass sets after 3 to 4 hr.; forms can be removed after 24 hr. After being fired at 1350° to 1450°C., the product had fine pores and a homogeneous structure. In another method which uses lightweight aggregate as a filler, 75% of foamed fired fire clay and 25% of aluminous cement are mixed with 60% water and fired after 20 to 24 hr. A specimen heated and quenched in cold water 50 times showed almost no change. The refractoriness of this

lightweight concrete was 1490°C.; its volume specific gravity was between 1.02 and 1.21. With refractory concrete, furnace walls may be made without expansion joints, because firing shrinkage and thermal expansion seem to compensate each other. According to Lepingle, the shrinkage of refractory concrete having 25% aluminous cement is 0.4 to 0.8% between 800° and 1000°C.; the maximum thermal expansion of 0.7% is reached at 850°C. The highest temperatures to which refractory concrete can be subjected are between 1200° and 1400°C. The minimum strength lies at 800°C.; under heavy load, refractory concrete cannot be used at this temperature. The casting of monolithic furnace walls and the embedding of firebrick in the zone of highest temperature are in the experimental stage. Firecrete, a lightweight refractory concrete made by Johns-Manville, hardens in 12 to 24 hr.; its volume specific gravity is 1.12, and its thermal conductivity is 50% less than that of ordinary firebrick. No firing shrinkage takes place up to 1310°C. An oil-fired forge furnace having a monolithic lining of this material was used continually at 1310°C. without damage from the cold air which penetrated frequently. In Babcock & Wilcox Co. boilers refractory concrete brick lasted for 8000 to 9000 working hr., while firebrick had to be replaced after 2000 hr. In the firing zone of a gypsum shaft kiln a lining of refractory concrete lasted for 2 years; firebrick had to be replaced every six months. The use of reinforced refractory concrete for door linings in coke ovens resulted in savings of 30 to 70% on refractory material. In tunnel kilns, car tops made of refractory concrete were 30 to 50% less expensive than other refractory material. 15 references. See "Hydraulic. . .," *Ceram. Abs.*, **17** [7] 253 (1938). F.E.S.

Refractory linings for protection of porcelain kilns from rapid wear. A. I. ZAKHAROV. *Keram. Sbornik*, **1939**, No. 1 (2), pp. 34–42.—The protective linings tested were made from grog, corundum, silicon carbide, and chromite. Their chief characteristics, such as chemical stability, adherence, thermal stability, shrinkage, refractoriness, water absorption, and apparent porosity, were tested. The results are given in tables. M.V.C.

Spalling and cracking of refractory materials. LEONARD HICKMAN. *Refrac. Jour.*, **16** [3] 95 (1940).—H. discusses the general causes and means of prevention of cracking in refractories during manufacture. The relative tendencies to spall of various types of refractory materials are also discussed. B.C.R.

Steam boiler brickwork. EDWARD INGHAM. *Brit. Clayworker*, **49** [585] 198–99 (1941).—Of the many causes of boiler deterioration, damp brickwork in contact with the plates is probably the greatest cause. The area of the plate covered by the setting should be reduced to a minimum by providing round-nosed or curvilinear seating blocks and side flue covers. From the time the boiler setting is completed, care should be taken to preserve the brickwork to prevent cracks which will permit the leakage of cold air into the flues. R.A.H.

Testing silica brick in the roof of the open-hearth furnace. G. ARISTOV. *Ogneupory*, **7** [5] 359–60 (1939).—A sample of silica brick from the roof of an open-hearth furnace was analyzed, and the results are tabulated. M.V.C.

Wonderstone—a unique refractory material. V. L. BOSAZZA. *Trans. Brit. Ceram. Soc.*, **39** [11] 369–76 (1940).—Wonderstone, a very ancient indurated clay occurring in southeastern Transvaal, is described, and some of its ceramic aspects are discussed. It approximates a fire clay in chemical composition, but no natural product is known at present which compares with it in ease of working. R.A.H.

BOOK

Manual of A.S.T.M. Standards on Refractory Materials, 1940–1941. Prepared by COMMITTEE C-8 ON REFRACTORIES, AMERICAN SOCIETY FOR TESTING MATERIALS, Philadelphia, Pa. 180 pp. Price, board cover, $1.50; cloth, $1.75.—All the A.S.T.M. standards pertaining to refractories are given in compact form. Other pertinent information and data on the testing and use of the materials, such as data on standard samples, surveys of service conditions of refractories, and recommended procedures, are included. R.A.H.

PATENTS

Broad coke oven. C. H. HUGHES (Hughes By-Product Coke Oven Corp.). U. S. 2,234,171 and 2,234,172, March 11, 1941 (Oct. 25, 1939). U. S. 2,234,173, March 11, 1941 (Jan. 24, 1940). U. S. 2,234,174, March 11, 1941 (April 25, 1940).

Calcium oxide-chromium oxide-zirconium oxide refractory. G. R. POLE. U. S. 2,231,944, Feb. 18, 1941 (Nov. 21, 1938).—A pressed and fired mixture consists substantially of calcium oxide, chromium oxide, and zirconium oxide in proportions corresponding approximately to 50, 25, and 25 mol %, respectively.

Calcium oxide-zirconium oxide refractory. G. R. POLE. U. S. 2,231,945, Feb. 18, 1941 (Nov. 21, 1938).—A pressed and fired mixture consists substantially of calcium oxide and zirconium oxide in proportions corresponding approximately to 40 and 60 mol %, respectively.

Furnace block, arch, and wall. RAY WILLIAM BELL. Can. 394,336, Jan. 28, 1941 (May 1, 1939). G.M.H.

Furnace-wall structure. C. M. FIXMAN (Laclede-Christy Clay Products Co.). U. S. 2,235,740, March 18, 1941 (Aug. 26, 1939).

Refractory. J. C. MCMULLEN (Carborundum Co.). U. S. 2,234,006, March 4, 1941 (July 5, 1938).—As a refractory material, a fused mass consists essentially of magnesia, lime, alumina, iron oxide, and phosphoric oxide.

Refractory cement composition. E. E. GAUNT AND STILLITE PRODUCTS, LTD. Brit. 532,463, Feb. 5, 1941 (July 22, 1939).

Refractory composition. J. C. MCMULLEN (Carborundum Co.). U. S. 2,235,077, March 18, 1941 (Oct. 28, 1938).—In a fused cast refractory article composed essentially of magnesium oxide and alumina and a fluoride selected from the group consisting of the fluorides of sodium, potassium, calcium, magnesium, barium, and aluminum, the magnesium oxide content is 50 to 80% and the alumina content is 10 to 45%, the article comprising one-half to 20% of the selected fluoride.

Refractory composition for dental molds. C. J. GROSSMAN. U. S. 2,233,701, March 4, 1941 (July 8, 1940).—A mold comprises a solution of zirconium oxychloride, magnesium trisilicate, magnesium oxide, and silica in combination with each other.

Refractory linings of furnaces having tubular walls. BENNIS COMBUSTION, LTD., AND A. W. BENNIS. Brit. 533,291, Feb. 26, 1941 (July 10, 1939).

Refractory mixture for cast metal molds. C. J. GROSSMAN. U. S. 2,233,700, March 4, 1941 (July 8, 1940).—The method of forming a refractory mold for cast metallic dentures comprises forming a mixture comprising at least 60% silica and 5 to 30% of a double Mg silicate compound of one of the metals zirconium and titanium, the silica having a particle size passing about 20 mesh with from 20 to 40% thereof passing 200 mesh and the silicate having a particle size passing about 200 mesh, forming the mixture into a plastic mass with phosphoric acid or similar binder, flowing the plastic mass over the surface of a pattern in a plurality of coatings to the depth and thickness desired, allowing the coatings to set, drying the coatings, and then slowly heating them to the desired preheat temperature of the mold before casting the molten metal therein.

Refractory mold material for cast metal products. C. J. GROSSMAN. U. S. 2,233,702, March 4, 1941 (July 17, 1940).—A refractory mold comprises at least 60% silica and magnesium trisilicate.

Silicate refractory. G. E. SEIL. Can. 394,765, Feb. 25, 1941 (May 28, 1937). G.M.H.

Terra Cotta

Ceramic building products. F. CHALAMEL. *Rev. Matériaux Construction Trav. Publics*, No. 343, pp. 53–56B; No. 344, pp. 67–70B; No. 345, pp. 79–80B; No. 346, pp. 91–93B; No. 347, pp. 100–103B; No. 348, pp. 111-15B; No. 349, pp. 127–31B; No. 350, pp. 139–42B; No. 351, pp. 155–56B (1938); No. 352, pp. 9–11B; No. 353, pp. 21–23B; No. 354, pp. 35–36B; No. 355, pp. 45–47B; No. 356, pp. 57–58B; No. 357, pp. 69–70B; No. 358, pp. 81–82B; No. 359, pp. 90–92B (1939).—The concluding parts of this series deal with stoneware tile, stoneware pipe, enameled stoneware, paving tile, etc., and their properties, characteristics, installation, maintenance, and application. The variety of ceramic building products, their adaptability to every use, and their advantages and beauty are pointed out and should recommend them for more extensive use in construction. See *Ceram. Abs.*, **18** [1] 26 (1939). M.V.C.

Ceramic stoneware for the chemical industry. ANON. *Ceramica*, **2** [9] 346–49 (1940).—The progress made in Italy in the application of stoneware for apparatus used in the chemical industry, such as centrifuge pumps for corrosive liquids and centrifuge ventilators for corrosive gas, filters, humidifiers, etc., is discussed briefly. Illustrated. M.V.C.

Chemical stoneware equipment. M. A. KNIGHT, JR. *Ind. Eng. Chem.*, **33** [2] 148–51 (1941).—Developments in the design and properties of chemical stoneware equipment for the chlorination industries are briefly reviewed. Illustrated. F.G.H.

Clay preparation in the stoneware industry. ANON. *Brit. Clayworker*, **49** [580] 107–109 (1940).—Generally, the methods of body preparation can be divided into two main groups, (1) pottery preparation and (2) heavy-clay-ware preparation. In continental pottery-clay preparation, the whole batch is finely ground in the wet grinding cylinder. The slurry is filter-pressed, and the cakes are extruded in the form of small clots and placed in the maturing cellar. Before using, the body is made homogeneous by pugging or kneading. In heavy-clay preparation, the constituents of the batch are put in layers into a suitable bunker and soaked. In large factories the mechanical or direct mixing of the materials and the making of clots is common practice. Details of each step in the preparation of clays for stoneware are given. R.A.H.

PATENTS

Ceramic insulating material. V. E. CAMPBELL, RAY HIGGINS, AND G. L. MCCREERY (Ohio Brass Co.). Can. 394,699, Feb. 18, 1941 (March 5, 1938).—The method of manufacturing dielectric material of high specific inductive capacity comprises heating rutile to a temperature slightly below the sintering point, mixing the preroasted titanium oxide so obtained with clay, water, and sodium titanium silicate to form a plastic mix, and firing to vitrification. G.M.H.

Flanged wall coping. J. P. DUFFY (Stillwater Clay Products Co.). U. S. 2,233,308, Feb. 25, 1941 (Sept. 16, 1940).

Pipe joints. CLAY CROSS CO., LTD., AND F. JERVIS. Brit. 532,657, Feb. 12, 1941 (Oct. 16, 1939).

Protective tile for covering underground cables. E. V. BYERS (H. J. Baldwin & Co., Ltd.). U. S. 2,235,356, March 18, 1941 (Dec. 11, 1939).

Wall coping. J. J. DYER. U. S. 2,232,905, Feb. 25, 1941 (July 20, 1940).

Whiteware

Comparative study of the compositions of ceramic products, starting with delicate faience. FRIED BIGOT. *Rev. Matériaux Construction Trav. Publics*, No. 350, pp. 133–36B; No. 351, pp. 151–52B (1938); No. 352, pp. 4–6B; No. 353, pp. 18–20B; No. 354, pp. 32–34B; No. 355, pp. 42–45B; No. 356, pp. 55–57B; No. 357, pp. 67–68B (1939).—Delicate faience is divided into the following categories according to its composition: (*a*) alkaline calcareous paste, generally with a cullet and calcium carbonate base, (*b*) calcareous paste, (*c*) calco-magnesia paste, and (*d*) paste containing iron oxide. The formulas for the compositions of these pastes are discussed. The action of lime is explained. The method of comparative examination and the principles for calculating the virtual composition are discussed. Common characteristics of composition of different faience pastes and indications of the nature of possible reactions between the different components are sought. M.V.C.

Composition of cement for binding porcelain with porcelain. E. KLIBINSKAYA. *Keram. Sbornik*, **1939**, No. 1 (2), pp. 51–52.—A newly developed apparatus for determining the coefficient of linear expansion of cement binder is described. Among the cements tested, the best results were obtained with those containing fused quartz and ground porcelain. M.V.C.

Elimination of lead and boric acid from whiteware and ceramic glazes. E. BERDEL. *Ber. Deut. Keram. Ges.*, **21** [4] 147–50 (1940).—As the war has brought back the problem of 25 years ago, B. considers the role of boric acid and of lead oxide in the history of ceramics. Under the leadership of Seger in the last two decades of the 19th century, an attempt was made to dispense with lead oxide on the grounds of health. Barite itself is poisonous and otherwise proved an unsatisfactory substitute for lead oxide. As long as boric acid was available, the problem of lead-free glazes could be solved (as with the Seger porcelain glazes) by replacing 0.5 to 1 SiO_2 with boric acid. This way is now blocked. Without boric acid, the kaolin and silica must be reduced to get a smooth flow in the glost firing. Glazes free of boric acid and lead cannot be used for temperatures below cone 1*a*, and B. has given up trying to use such glazes without a small addition of lead oxide, preferably as white lead, in the batch. W.H.H.

Glazes free of lead and boron. FRITZ ALZNER. *Ber. Deut. Keram. Ges.*, **21** [1] 13–18 (1940).—Papers recently published on glazes without lead or boron deal with a similar composition. Glazes having a composition within the following limits have been suggested:

$$\left.\begin{array}{l} 0.2\text{–}0.3\ K_2O \\ 0.25\text{–}0.35\ CaO \\ 0.08\text{–}0.16\ MgO \\ 0.15\text{–}0.30\ BaO \\ 0.08\text{–}0.12\ ZnO \end{array}\right\} \quad 0.15\text{–}0.25\ Al_2O_3 \quad 1.5\text{–}2.3\ SiO_2$$

Glazes with the highest alkali content are most fluid and possess the best luster but are especially uncertain. They are very sensitive to furnace gas and can seldom be placed on the usual whiteware body without crazing. Previously, calcium and sodium compounds were introduced into glazes chiefly as carbonates and nitrates. If the alkalis are replaced by equivalent amounts of alkali silicates, the safety in the use of lead- and boron-free glazes is greatly increased. W.H.H.

Lead-free whiteware glazes resistant to sulfurous acid. W. STEGER. *Ber. Deut. Keram. Ges.*, **21** [1] 3–12 (1940).—It is generally considered that lead-free glazes are more sensitive to sulfur in kiln gases than glazes containing lead. S. made tests on 19 lead-free glazes exposed to sulfurous acid, air, and steam in an electrically heated kiln and concludes that the problem of preparing sintered, lead-free, whiteware glazes for Seger cones 08*a* to 01*a*, with good resistance to kiln gases containing sulfur, may be effectively solved by suitable composition of the glaze. Of the oxides of the alkali metals, sodium and lithium oxides must be avoided; borax, therefore, cannot be used as a source of boric acid. Calcium oxide, not lithium oxide, must be used to replace sodium oxide, and barium oxide must be left out of the lead-free glazes. It is effective to

replace a part of the harmless calcium oxide with magnesium oxide, which is believed to be even better than calcium oxide for making lead-free glazes resistant to kiln gases containing sulfur. The best content of boric acid is, on the average, 15% with 55% silica in the melted glaze. More than 15% boric acid is not necessary. A decrease to 10% B_2O_3 with an increase of the silica content to about 60% makes the melting of the glaze more difficult, but this does not prevent the preparation of lead-free glazes if the glost-firing temperature is adjusted correspondingly. W.H.H.

Manufacture of sanitary ware. ANON. *Ceram. Age*, **36** [5] 135 (1940).—The causes of peeling and cracking are briefly discussed. F.G.H.

Occurrence of scumming in hard porcelain. FRIEDRICH DETTMER. *Ber. Deut. Keram. Ges.*, **19** [6] 235–36 (1938). —The investigations of Kieffer and Czech ("Origin . . .," *Ceram. Abs.*, **18** [7] 188 (1939)) do not refer to an earlier paper by D. (*Ber. Deut. Keram. Ges.*, **17** [12] 629–30 (1936)) in which he pointed out that, according to H. von Wartenberg, transpositions take place between silicic acid and hydrogen. These transpositions begin at 1200°C. but are more pronounced at higher temperatures. The determination of Kieffer and Czech is interesting, viz., that the differences in the amount of scumming with an uncontaminated blast and with a blast loaded with sulfides were not great enough to warrant the assumption, with complete safety, of a connection between the presence of sulfur and the occurrence of scumming. Only the introduction of water caused a recognizable difference. Furthermore, the authors expressly emphasize the fact that, under oxidizing conditions, not the slightest occurrence of scumming could be observed. Their results thus agree with those of D., that the scumming is caused by reduction at the end of the firing. As scumming occurs when firing with wood, which contains little or no sulfur, D. assumes that the chief cause of scumming lies in hydrogen, in the hydrocarbons, and finally also in hydrogen sulfides when they can occur. SiH_4 can exist temporarily, but it is converted into Si or SiO_2 by the addition of air and the lowering of the temperature. Factors other than sulfur compounds in the reducing gases may play an active part in causing scumming. This is especially probable since, although silicic acid is the main constituent of the specks produced by scumming, other constituents are present in small amounts, e.g., Al_2O_3 and CaO with whiteware and manganese and iron oxides in ivory glazes. W.H.H.

Reversible darkening in daylight of glazes containing titanium. W. O. WILLIAMSON. *Trans. Brit. Ceram. Soc.*, **39** [11] 345–68 (1940).—Many glazes containing rutile, artificial titanium dioxide, or both darken reversibly in daylight. The phenomenon is termed phototropy or reversible photosensitivity and is sometimes extraordinarily striking. The effect may appear even though the natural or artificial titanium dioxide is not itself phototropic. The purity of the titania employed is no guarantee against the appearance of photosensitivity in a glaze, as recrystallization of the titania in the glaze allows the phenomenon to be initiated, presumably by the trapping of impurities in the growing crystals. The phototropy is a property of the suspended crystalline matter in the glaze and not of the glassy part. It can be interpreted in the light of earlier work on the occurrence of reversible photosensitivity in artificial materials containing rutile. A series of titanium containing glazes fired electrically on a short laboratory cycle was studied. The investigation of such glazes is complicated by the possible existence of titania in three crystalline modifications, viz., rutile, anatase, and brookite. Artificial nonphotosensitive anatase of considerable purity gave rise to phototropic glazes in which the phototropy disappeared on harder firing. X-ray analysis showed that the calcination of the anatase with a small proportion of glaze converted it into rutile. This rutile was phototropic. Commercial photosensitive titanium dioxide behaved similarly to the anatase when used as a glaze constituent. A sample of natural rutile gave very photosensitive glazes in which the phototropy existed over a longer firing range than in glazes made from artificial rutile or artificial anatase. A second sample of natural rutile gave no phototropic glazes. The second sample was darker than the first, and the two samples, whether recrystallized in a glaze or in the presence of a mineralizer (common salt), bore a similar relation. The failure of the second sample to show phototropy on recrystallization is believed to be connected with the dark color of the resulting crystals. The iron content of the second sample was above that of the first, and when it was artificially lowered the sample produced phototropic glazes. In glazes made with artificial anatase and artificial or natural rutile, the sequence of events, after the cooling of trials drawn at increasing temperatures, is probably an initial formation of new crystals of photosensitive rutile followed by the suppression of this phase by a second nonsensitive phase, perhaps a titanate. Glazes containing natural rutile or artificial titania may become blue when fired to 1300°C. on a short cycle under oxidizing conditions. R.A.H.

Use of a high sericite pyrophyllite in vitreous bodies. EMERSON W. EMRICH. *Jour. Amer. Ceram. Soc.*, **24** [4] 141–44 (1941).—Seven tables, 2 references.

Whiteware and stoneware bodies containing bentonite. HANS LEHMANN. *Ber. Deut. Keram. Ges.*, **20** [1] 2–11 (1939).—By the addition of bentonite to nonplastic crude kaolin, the plasticity, green strength, and workability on the potter's wheel are so greatly increased that these synthetic whiteware bodies approach those made from plastic whiteware clays. The purpose of this paper is to compare the characteristics of such synthetic whiteware clays and the bodies made from them with those of the customary clays and bodies. Both laboratory and production tests were made. The Enslin apparatus, developed for use with soils, was used for measuring the "water values," showing the amount of water which the clays would absorb by capillarity. The nonplastic crude materials showed absorptions of between 30 and 40% with the exception of muscovite, which held large amounts of water between the cleavage surfaces of the separate pieces of the mica. With kaolins, the difference was clear between nonplastic and plastic. The highest water value was found for pitchstone kaolin. Extraordinarily high water values were found for bentonite; in fact, the values for Ca bentonite were 4 to 5 times those for nonplastic kaolin, and those for Na bentonite were up to 10 times as high. Both the green strength and the plasticity (Pfefferkorn's method) increased as the water value increased. There is the practical problem of selecting kaolins which, when combined with available German bentonites, give values of plasticity and green strength corresponding to those usually found in practice. A mixture was made of 75 kaolin, 20 whiteware clay, 5 sand, and 4% ceramic bentonite which compared favorably with the usual commercial mix as shown in the following table.

Test	Commercial mixture	Bentonite mixture
Enslin water value	70	85
Plasticity (Pfefferkorn)	34	40
Green strength	38	51
Shrinkage	10	10

Practical use of this bentonite mix showed that the expectations based on the laboratory tests were fulfilled. The workability of the paste proved even better than that of a paste made with a large part of highly plastic whiteware clay. The molded pieces showed a completely normal drying and were easily worked on account of their high green strength, which should also be an advantage in decreasing breakage. All other processes to produce the finished ware could be carried out in a normal manner. The use of bentonite in stoneware mixes was also investigated. By adding bentonite to a commercial mix, the green strength was increased from 11.9 to 28.0 kgm. per $cm.^2$. W.H.H.

PATENTS

Ceramic body for spark-plug insulators. T. G. McDOUGAL, A. H. FESSLER, AND H. B. BARLETT (General

Motors Corp.). U. S. 2,232,860, Feb. 25, 1941 (Jan. 7, 1939).—A spark-plug insulator in the form of a dense, impervious body consists of a sintered mixture of aluminum oxide and 6 to 50% thorium oxide.

Ceramic electric insulating body. WERNER RATH. U. S. 2,235,489, March 18, 1941 (Dec. 24, 1937).—An electric insulating body of sintered ceramic material having a high dielectric constant and containing at least 70% of titanium dioxide and an oxide of a heavy metal belonging to group VIA of the periodic system of the elements and having an atomic weight between 96 and 184 inclusive.

Ceramic support. W. F. SMITH. U. S. 2,233,434, March 4, 1941 (Dec. 6, 1937).

Gas-tight joint between the electrode and the ceramic body. ARTUR MÖHRLE AND EDGAR SACHS (R. Bosch G.m.b.H.). U. S. 2,235,325, March 18, 1941 (April 25, 1939).

Glow spark plug. ELI WHITE. Can. 393,887, Jan. 14, 1941 (Aug. 11, 1939). G.M.H.

Making ceramic products. D. E. LOWER. U. S. 2,232,462, Feb. 18, 1941 (Feb. 21, 1938).—(4) A method of making a ceramic product consists in forming a ceramic body from selected ceramic materials, treating the surface of the body solely with a solution consisting of water and phosphoric acid, and then firing the body. (8) A method of making ceramic bodies consists in making a slip of a mixture of selected vitrifiable materials and water, forming the slip into a body of the desired shape in a mold, removing the formed ceramic body from the mold, treating the surface of the body solely with a solution consisting of water and phosphoric acid, drying the body, and then firing it.

Manufacture of ceramic ware. G. J. BAIR (N. S. Garbisch). U. S. 2,233,575, March 4, 1941 (Dec. 16, 1938).—A process of forming pottery bodies comprises incorporating with pottery clay and crushed flint a flux consisting of glass crushed to pass a screen of 200 mesh, the glass, after crushing and prior to incorporation into the pottery body, having been conditioned to remove surface alkali from the particles thereof by subjecting it to the action of a strong mineral acid and then washing out the acid.

Manufacturing electric insulators. J. J. TAYLOR (Ohio Brass Co.). U. S. 2,234,391, March 11, 1941 (Jan. 17, 1939).

Manufacturing pottery with incised or incrusted designs. G. A. BAUER. U. S. 2,235,665, March 18, 1941 (April 20, 1940).

Producing a ceramic electrical insulation. STEATIT-MAGNESIA A.-G. Ger. 684,932, Nov. 16, 1939 (June 5, 1934); VIII*b*/21*c*. 2.01.—An impervious electrical insulator is produced by sintering a mixture of magnesium oxide and titanium dioxide. The resulting product is magnesium titanate. **Ger. 688,239,** Jan. 25, 1940 (Jan. 6, 1936); VI/80*b*. 8.13; addition to Ger. 684,932.—The magnesium titanate is produced from its constituents, pressed under high pressure, and sintered at a temperature of 1400° to 1550°C. This material is introduced in a finely pulverized form as an essential constituent in the batch of the ceramic electrical insulating object. D.A.B.

Producing ceramic products, especially spark-plug elements. EMIL KLINGLER, GERHARD WEITBRECHT, AND EUGEN DREHER (Robert Bosch G.m.b.H.). Ger. 680,250, Aug. 3, 1939 (Dec. 1, 1936); VI/80*b*. 24.04.—Ceramic products, especially spark-plug elements, are produced by forming and sintering a mass of highly refractory nonplastic material containing an organic binding agent. A suitable thermoplastic resin is added to the ceramic mass in such an amount that it can be sprayed; it is then worked according to known spraying methods. ALFRED BRÄNDEL (Robert Bosch G.m.b.H.). Ger. 680,648, Aug. 17, 1939 (Sept. 14, 1937); VI/80*b*. 24.04; addition to Ger. 680,250.—A sprayable mass is used which contains finely divided metallic aluminum. D.A.B.

Producing highly sintered ceramic materials. ROSENTHAL-ISOLATOREN G.M.B.H. Ger. 681,316, Aug. 31, 1939 (Sept. 24, 1936); VI/80*b*. 8.19.—Calcium silicate, in the form of phosphorus furnace slag resulting during phosphorus production, is used as an admixture in ceramic products containing highly sintered aluminum or magnesium silicate. D.A.B.

Spark plug. G. C. BARNES (United Aircraft Corp.). U. S. 2,233,660, March 4, 1941 (April 24, 1940).

Spark plug. WILLIAM HARPER, JR. (H. B. Motor Corp.). Can. 394,425, Feb. 4, 1941 (March 8, 1939). G.M.H.

Spark-plug insulators. GENERAL MOTORS CORP. Brit. 533,130, Feb. 19, 1941 (Oct. 14, 1938); addition to 481,769.

Vitreous body. MARCELLO PIRANI AND J. H. PARTRIDGE (Canadian General Electric Co., Ltd.). Can. 394,873, Feb. 25, 1941 (Dec. 7, 1937). G.M.H.

Equipment and Apparatus

Ball-mill design. D. W. RUDORFF. *Eng. & Boiler House Rev.*, **54** [6] 180 (1940).—Grindability or relative resistance to pulverization and the influence of moisture content upon ball-mill output are discussed. B.C.R.

Developments in fine-ceramic machinery. WALTER SCHLEGEL. *Ber. Deut. Keram. Ges.*, **20** [1] 18–40 (1939).—The present need is to improve methods of production in order to save labor. New machines brought out in response to this need are described. All steel has the same characteristics, and it is comparatively easy to build machines for working steel, but ceramic materials vary greatly, and this causes difficulties which can be solved only by cooperation between the machine builder and the user. Constancy of product can be obtained only by replacing periodic processes by continuous processes. In the installation of a conical tube mill, the feldspar or quartz is first broken by rollers, and the dried material is brought by a conveyer to a silo, from which it is conveyed uniformly to the tube mill. The ground material is taken by a bucket conveyer to an air separator, and the material of the desired fineness is then automatically bagged. This installation produces about 1200 kgm. quartz ground to pass a mesh of 10,000/cm.^{2}. In spite of higher first cost, rubber piping has proved preferable to sheet iron because of its longer life, ease of transport, and avoidance of contamination with iron of the material passing through it. New, more efficient, magnetic separators are available for removing iron from fluid pastes. The filter press has the disadvantages of periodic action, segregation of the paste during filtration, and variable moisture content of the cake. Recent presses use, instead of cloths, a porous ceramic material which lasts for 2 to 4 years. The disadvantages above mentioned remain, unless continuously revolving filters are used as in the chemical and cement industries. In the U. S., 14 large ceramic plants are provided with such filters. In one case the material from the filter is conveyed directly to a vacuum press. The vacuum press is an unusually important improvement, originating in the U. S. as a wire cutting press. Some brick presses have been rebuilt to employ a vacuum, and some are entirely new. The filter cake, after having been reduced to a rod shape, is fed in small slices into the vacuum chamber and again formed into a rod. In a third type of vacuum press, there is, in the vacuum chamber, an upright auger which serves the purpose of cutting the paste, compressing it, and keeping the vacuum chamber free. It is especially suitable for very plastic pastes. The more difficult unsolved problem is to make homogeneous, structure-free rods of paste. Even if a paste is 100% deaired, it may be impossible to use it on account of its structure. S. discusses finishing machines. The chief difficulty with turning machines for cups is that they are not economical unless a large number of cups of the same design are to be made. A similar machine is the automatic machine for turning dishes, which has been in the process of development for eight years. The paste is supplied to it in a lump, not in a

sheet, and it takes only 2 sec. to turn a dish. The dishes and other turned products should be dried in a cupboard drier, the products passing in at one end and out at the other. The advantages are greater for plates than for cups. A plate weighing 1000 gm. and requiring the evaporation of 250 gm. of water can be dried in 80 to 90 min. Drying cabinets are used for tile, porcelain, and even brick. Very little progress has been made in Germany in mechanizing glazing, except for tile. Plates and dishes are glazed by spraying machines in the U. S., and silk-screen printing is used for decorating plates and cups under the glaze. The friction clutch is unsatisfactory in automatic presses for making tile, and this has led to the development of the toggle lever system, so arranged that each tile is subjected to a light pressure and then to a high pressure. The full advantage of these automatic presses is obtained when they are used in combination with a tile-cleaning machine. W.H.H.

Developments in machines for fine ceramics—recent vacuum methods for deairing clay. OTTO MANFRED. *Ber. Deut. Keram. Ges.*, **20** [7] 326–29 (1939).—This paper is supplementary to one by Schlegel (see preceding abstract). A known disadvantage of the filter press is the uneven distribution of moisture in the cake. When vacuum deairing is used, the object should be not necessarily to obtain the highest possible vacuum but to obtain the greatest possible uniformity of product. For this purpose, the forming machine should follow immediately after the vacuum mixer. German and American patents on deairing are discussed. W.H.H.

Draft gauges for firing equipment. W. H. PUGSLEY. *Power*, **85** [2] 118–19 (1941).—P. summarizes briefly the points to remember in applying draft gauges to different kinds of firing equipment. Illustrated. See "A B C's . . .," *Ceram. Abs.*, **20** [1] 24 (1941). F.G.H.

Drying and dehydration of clay in the suspended state. K. A. NOKHRATYAN. *Ogneupory*, **6** [5] 1242–44 (1938).—N. suggests combining drying and grinding in one apparatus for clay and grog in the production of grog products. M.V.C.

Electric counter for thin-section analysis. CORNELIUS S. HURLBURT, JR. *Amer. Jour. Sci.*, **237** [4] 253 (1939).—By means of an electrical counter, six minerals can be measured and recorded simultaneously by the Rosiwal method. Micrometric measurements of a thin section may be made in less than half the time required by other methods. B.C.R.

Flow of muds, sludges, and suspensions in circular pipe. D. H. CALDWELL AND H. E. BABBITT. *Ind. Eng. Chem.*, **33** [2] 249–56 (1941).—A theoretical analysis of the flow of sludges in circular pipe is presented. Two distinct types of flow occur, depending upon the velocity; they have been termed "plastic flow" and "turbulent flow." The velocity at which plastic flow changes to turbulent flow is called the "critical velocity." Equations are developed and verified experimentally for determining friction losses for plastic flow and for turbulent flow in circular pipe. An equation for the determination of the critical velocity is also presented, together with experimental verification. Methods of determining the significant constants in the plastic-flow and critical-velocity equations are described. Illustrated. F.G.H.

Hard-facing machine parts. C. H. S. TUPHOLME. *Mining Mag.*, **63**, 70–75 (1940).—Detailed directions are given for applying Stellite to drill chucks and other parts. This material also has many applications on mine pumps, e.g., for hard-facing sleeves for shafts, the edges of the impeller blades, and seal rings. It is advisable not to hard-face a shaft directly but to apply the hard facing to a sleeve and then possibly to shrink the sleeve onto the shaft. W.D.F.

Laboratory kryptol furnace for high temperature. A. I. ZAKHAROV. *Keram. Sbornik*, **1939**, No. 1 (2), pp. 49–50.—A temperature up to 1900°C. can be reached using a.c. or d.c. with 40 to 80 volts and 180 to 230 amp. M.V.C.

Rapid method for calibration of flowmeters. HERMAN J. MEURON. *Ind. Eng. Chem., Anal. Ed.*, **13** [2] 114 (1941).—Details of the calibration are given. Illustrated. F.G.H.

Sifting mechanically through standard testing sieves. F. A. W. DAVIS AND D. A. DEADERICK. *Eng. Mining Jour.*, **141** [9] 58 (1940).—A $^3/_4$- x 12- x 18-in. board has a semicircular hole cut in one end, in which the bottom sieve is held by rubber tubing. A 10-lb. counterweight and frame hold the sieves down. A Model V-9 Syntron electric vibrator with an electric controller is mounted just in back of the sieves and nearly touching them. The other end of the board is bolted to a table or shelf, with rubber stoppers interposed. The apparatus has a capacity of ten high sieves and can be used for either wet or dry sieving. W.D.F.

Simply constructed color comparator. RICHARD H. WILHELM. *Ind. Eng. Chem., Anal. Ed.*, **13** [2] 123 (1941).—Details of construction are given. Illustrated. F.G.H.

Temperature control. W. M. BARRATT. *Glass*, **18** [1] 13 (1941).—B. describes the equipment necessary for measuring and controlling temperatures in a gas-fired furnace. B.C.R.

Tests with the recording plastometer of Brabender. K. ZIMMERMANN. *Ber. Deut. Keram. Ges.*, **21** [4] 135–41; [5] 206–208 (1940).—The Brabender instrument (*Ceram. Abs.*, **18** [5] 133 (1939)) has been used for testing dough, and it was thought that it might be applicable to clay. A small kneader is driven by a cradle dynamometer arranged so that the resistance to kneading is transferred to the dynamometer, whose casing has the tendency to revolve in the opposite direction to the kneader. The variations in rotation are damped by a dashpot and transferred to platform scales. The movements of the platform, and thus the variations in resistance of the dough to kneading, are automatically recorded. The kneader and dashpot are maintained at constant temperature by oil circulation and a thermoregulator. Mechanical and chemical analyses are given for seven clays which were tested, together with illustrations of the autographic records from the kneading tests. It was found that the water content, either when the resistance was just great enough to be recorded or when the paste was stiffest, was not a suitable basis for judging the characteristics of a clay. The stiffest consistency gives an idea of the workability of the clay and thus in certain cases can be a useful means of plant control. Since the differences in water content at stiffest consistency are not great, it is preferable to compare the stiffness of different clays with the same water content, e.g., 20%. The change in consistency with change in water content, e.g., from 20 to 22%, may also be noted. The more kaolin in a clay, the more sensitive the clay is to changes in water content. W.H.H.

Time-saving adaptation for photomicrography. JOHN A. QUENSE AND WILLIAM M. DEHN. *Ind. Eng. Chem., Anal. Ed.*, **13** [1] 68 (1941).—Details of construction and operation are given. Illustrated. F.G.H.

Use of a diagram for calculating the interior volume of a ceramic object having an axis of revolution. H. CHATENET. *Rev. Matériaux Construction Trav. Publics*, No. 354, pp. 25–26B (1939).—A rapid and exact method for establishing the interior volume of a piece of ceramic ware with an axis of revolution from a diagram of the interior outline is explained and illustrated. M.V.C.

SEPARATE PUBLICATION

Grinding Pebbles and Tube-Mill Liners. ROBERT W. METCALF. *U. S. Bur. Mines Information Circ.*, No. 7139, 5 pp.—M. discusses the uses, imports, domestic production, and possible domestic sources of grinding pebbles and tube-mill liners. R.A.H.

PATENTS

Apparatus for the drying of articles of ceramic materials by using high-frequency electrical fields. SIEMENS-SCHUCKERTWERKE A.-G. Ger. 649,587, Aug. 12, 1937 (April 16, 1936); V/82*a*. 1.01. D.A.B.

Broiler ceramic burner unit. STEPHEN N. BOBO. Can. 394,491, Feb. 11, 1941 (Dec. 22, 1939; in U. S. Aug. 31, 1939). G.M.H.

Drying equipment for tile and similar ceramic products. ERDUIN SCHONDORFF. Ger. 682,573, Sept. 28, 1939 (July 20, 1937); V/82*a*. 2.—The air for drying the objects is passed through a number of conducting channels which are provided with double wing-shaped installations; these channels run oblique to the longitudinal direction of the chamber and are located underneath the drying chamber. The drying air is passed into a space located over the drying chamber through openings located at regular intervals in the drying chamber ceiling. D.A.B.

Machine for preparing clay, etc. CHRISTIAN GIELOW. Ger. 689,144, Feb. 22, 1940 (March 20, 1937); VI/80*a*. 1.05.—The charge is pressed, by means of stirring arms, through openings of an oblong chamber wall which opens at the top. D.A.B.

Manufacture of glazed ceramic bodies. N. S. GARBISCH. Brit. 532,780, Feb. 12, 1941 (Nov. 29, 1938).

Mixing drum. PAUL RÖBER (Geb. Röber G.M.B.H). Ger. 690,194, March 28, 1940 (June 30, 1939); I/*b*/12*e*. 4.01.—A drum for mixing solid materials or solids with liquids is described. D.A.B.

Process and apparatus for forming ceramic bodies. N. S. GARBISCH. Brit. 532,781, Feb. 12, 1941 (Dec. 16, 1938).

Process and apparatus for the manufacture of molded brick. V. EHRENHAFT. Brit. 532,453, Feb. 5, 1941 (July 18, 1939).

Stamping equipment for producing five-sided hollow brick. ALFRED HANSMANN. Ger. 682,572, Sept. 28, 1939 (Feb. 23, 1937); VI/80*a*. 43.10. D.A.B.

Kilns, Furnaces, Fuels, and Combustion

Electric tunnel kiln and its development in the ceramic industry. A. RITTGEN. *Ber. Deut. Keram. Ges.*, **19** [4] 113–30 (1938); translated in *Ceram. Ind.*, **32** [6] 43–46; [7] 47–50 (1939).—There has been great progress in the last five years in the use of electricity for heating in the ceramic industry. Only with electric heat is it possible to dispense with saggers or muffling of the flame. Electric tunnel kilns may be used for (*a*) firing decorations on whiteware and porcelain, annealing porcelain, and annealing colored whiteware and porcelain; (*b*) firing glazed and unglazed whiteware and fire clay; and (*c*) firing porcelain ware and insulators. For *a* the temperature is 700° to 900°C. in an oxidizing atmosphere so that the chromium-nickel resistances present no difficulties. It may be expected that electric tunnel kilns for firing decorated ware will increase in use, especially in countries where electricity is cheap and is most generally used. This is also true of the electric porcelain biscuit firing kiln. This firing was previously accomplished (as it were, gratis) in the upper story of the coal-heated circular kiln. In the porcelain industry, the conveyer system is also being increasingly used, and thus there is a call for the tunnel kilns. In the whiteware industry, there has been a much greater increase in the use of tunnel kilns. A kiln built in 1931 produces 3000 tile per 24 hr. at a temperature of about 1200°C. A two-track kiln built in 1933 produces 7200 tile in 24 hr., using about 1.55 kw.-hr. per kgm. of ware. Small kilns built in 1934 used only 0.4 to 0.8 kw.-hr. per kgm. of ware but were less satisfactory than expected, and this type of kiln has no future. The difficulties were about the same as those found with the old ceramic tube furnaces, and the cost of repair of the complicated conveyer system was high. Large kilns with two or more tracks, however, have given satisfaction, one of the first being for sanitary ware. The temperature of the double tunnel kiln is 1300°C., and the daily output is 6500 kgm. of fire clay and sanitary porcelain. The current used is 1.3 to 1.5 kw.-hr. per kgm. of ware, being increased by the fact that the ware cannot be closely packed. This kiln has been run continuously since it was first started early in 1933. The first three-track tunnel kiln was built in 1936. The resistance heaters are of silicon carbide, and the highest temperature is 1320°C. With an output of about 15,000 kgm. of mixed whiteware per 24 hr., the current required is 1.1 kw.-hr. per kgm. of ware. This kiln has been in constant operation for 1½ years. The number of these large kilns is increasing, since experience has shown that the modern electric tunnel kilns have undoubtedly proved their value for the types of ware mentioned under *b*. Many attempts have recently been made to use the electric tunnel kiln in the field of porcelain firing. A double tunnel kiln for hard porcelain has been in operation in Switzerland since May, 1937. The daily output is 3500 kgm., requiring 3.62 kw.-hr. per kgm. The highest temperature tunnel is at 1410°C. In general, electric tunnel kilns for porcelain are economically inferior to the gas- and oil-heated kilns in regard to the durability of the resistance heaters, the consequent danger of contact, and also the high price of these resistances. The electric tunnel kiln has been used almost exclusively in the application of electric heating. The steps in the development of tunnel kilns are shown. To explain their great success in the whiteware industry, data are given on practical operation in recent years on a large scale. W.H.H.

Heat transfer in the flow of gas through a bed of solid particles. O. A. SAUNDERS AND H. FORD. *Jour. Iron & Steel Inst.* [London], **141** [1] 291–328 (1940).—From application of the theory of dimensions to the heat transfer in the flow through a bed of solid particles, it is concluded that the heating up of the bed depends only upon its shape and upon the two dimensionless groups $V\tau c'/lc$ and Vlc'/k (where V = velocity of gas, l = characteristic linear dimension of bed, c = specific heat per unit volume of material of particles, k = conductivity of particles, c' = specific heat per unit volume of gas, and τ = time). The group Vlc'/k may be neglected if the particles are small or their conductivity is high. To verify the theory experimentally, hot air was passed through beds of various depths of steel, lead, or glass spheres of diameters up to 0.25 in. The results for the different sizes, velocities, and materials could be correlated with $V\tau c'/lc$, showing that the effect of temperature differences within the particle was negligible in the experiments. Curves are given for calculating the variation of gas temperature through a given bed at any given moment. The time taken to attain a given temperature at a given depth of bed is directly proportional to the specific heat and density of the particles, inversely proportional to gas velocity, and only slightly affected by particle size. Curves are also given for heat transfer. The highest value for Vlc'/k found in the experiments was about 4, corresponding to diameters of 0.25 in. and 11 in. for glass and steel, respectively, at an air speed of 2 ft. per sec. The results, therefore, are strictly applicable only up to these sizes; rough calculations show that the errors in using them up to sizes two or three times those quoted are probably only a few per cent. A discussion is included. V.D.F.

Moisture relations of banded ingredients in an Illinois coal. O. W. REES, G. W. LAND, AND F. H. REED. *Ind. Eng. Chem.*, **33** [3] 416–19 (1941).—The moisture-humidity relations of the banded ingredients vary in relation to each other and to those of the whole coal. The moisture-humidity curve for vitrain lies above that of whole coal, that of clarain lies very near that of whole coal, that of durain is below that of whole coal, and that of fusain is below all others up to about 96% humidity, at which value it rises sharply well above all others. The moisture values of the whole coal at different humidities appear to be weighted composites of the moisture values of the component ingredients. The equilibration and calculated pore-size data appear to correlate well with the capillary theory for the occurrence of moisture in coal. The variations in the moisture relations of whole coal and those of its component banded ingredients as shown by studies on this one coal have a distinct bearing on moisture in commercially prepared coals. Illustrated. F.G.H.

SEPARATE PUBLICATIONS

Annual Report of Research and Technologic Work on Coal, Fiscal Year 1940. ARNO C. FIELDNER AND W. E. RICE. *U. S. Bur. Mines Information Circ.*, No. 7143, 50 pp. Free. R.A.H.

Splint Coals of the Appalachian Region, Their Occurrence and Petrography, and Comparison of Chemical and Physical Properties with Associated Bright Coals. G. C. SPRUNK, W. H. ODE, W. A. SELVIG, AND H. J. O'DONNELL. *U. S. Bur. Mines Tech. Paper*, No. 615, 59 pp. R.A.H.

PATENTS

Supporting devices for tile or other ceramic articles during firing. J. W. A. LOVATT, W. M. LOVATT, AND J. B. C. CLIFFORD. Brit. 532,016, Jan. 29, 1941 (Aug. 19, 1939).

Geology

Aluminum and bauxite. C. L. MANTELL. *Mineral Ind.*, **48**, 7–27 (1939).—M. gives data on the production of bauxite in each of the producing countries during 1939, in which year a new high total tonnage was reached. B.C.R.

Calculation of geological age. NORMAN B. KEEVIL. *Amer. Jour. Sci.*, **237** [3] 195–214 (1939).—New equations developed for computing the age of rocks and minerals from radioactivity data are given and discussed. By a suitable choice of equations, any desired degree of accuracy in calculations of the age can be obtained for all methods involving the accumulation of lead and helium from the thorium, uranium, and actino-uranium series. B.C.R.

Chromite. W. F. BRAZEAU. *Mineral Ind.*, **48**, 65–80 (1939).—U. S. imports of Philippine chrome ore represented 44% of the total, whereas none was imported prior to 1935. Second in importance was Cuba, followed by South Africa, Southern Rhodesia, Turkey, New Caledonia, and Greece. Production figures and probable deposits for each producing country are given. B.C.R.

Colorado cerite. ROSS A. HANSON AND D. W. PEARCE. *Amer. Mineralogist*, **26**, 110–20 (1941).—Further study of this mineral showed a black border of allanite and inclusions of fluorite. Chemical analysis shows the formula $2CaO \cdot Al_2O_3 \cdot RE_2O_3 \cdot 2SiO_2$. Cerite analysis usually shows little or no alumina and some H_2O. The allanite was also analyzed. The individual rare earths were determined spectrographically for each mineral by the line-density method; they were much the same for the two minerals. W.D.F.

Contribution of diatoms to the sediments of Crystal Lake, Wisconsin. PAUL S. CONGER. *Amer. Jour. Sci.*, **237** [5] 324 (1939); see "Origin . . .," *Ceram. Abs.*, **19** [4] 99 (1940); "Sediments . . .," this issue, p. 126. B.C.R.

Demand for Southern minerals. GEORGE C. BRANNER. *Mfrs. Record*, **110** [1] 24 (1941).—There is an increased demand in Georgia for clay, asbestos, mica, manganese, bauxite, and chromite. Additional capacity will be required. B.C.R.

Deposition of calcium sulfate from sea water. E. POSNJAK. *Amer. Jour. Sci.*, **238** [8] 559 (1940).—Stability relations of gypsum and anhydrite in solutions of sea salts are of considerable geological interest, as many deposits of these minerals are generally considered to be of marine origin. Sea water is unsaturated with respect to calcium sulfate, and only after its salt content has increased by evaporation to 3.35 times the usual salinity can deposition occur. Sedimentary marine deposition of pure anhydrite must either be at least partly derived from originally deposited gypsum or have been formed close to or above 42°C., the transition point of the two minerals. B.C.R.

Detection of clay minerals in soil mortars by photoelectric cell. B. H. KNIGHT. *Nature*, **147** [3714] 27–28 (1941).—K. treats the soil mortar with a solution of malachite green for 10 to 15 min. and filters the liquid into a glass cell. The degree of decolorization is a measure of the amount of base exchange between the clay minerals and the stain. This is evaluated quantitatively by placing the filtrate between a light source and a photoelectric cell having a sensitive galvanometer in circuit. Clay fractions dominantly quartzose in type remove little stain, while those of kaolinite or beidellite produce an almost clear filtrate. K. emphasizes the importance of determining the nature of the clay content of mortars to avoid including material of the beidellite type which has dangerously high expansive properties with increase of moisture content. J.L.G.

Distinction between calcite and dolomite. JOHN RODGERS. *Amer. Jour. Sci.*, **238** [11] 788 (1940).—The most satisfactory method for distinguishing calcite from dolomite on polished surfaces is that of staining in molar $Ca(NO_3)_2$ solution for 5 to 6 hr. at room temperature, followed, without washing, by immersion in strong ammonia for several seconds. The excess precipitate may then be rubbed off without danger of removing any of the stained material. A staining period of $2^1/_2$ to 4 hr. is sufficient when calcite is present in excess. The $Ca(NO_3)_2$ produces a solution having a pH of less than 7, thus reacting as a weak acid upon the calcite and leaving a colored coating. Other rhombohedral carbonates react to weak acid in the same way as dolomite, and the orthorhombic carbonates, except cerussite, react similarly to calcite. B.C.R.

Effective methods in a "gyp" quarry. FLOYD SUTER BIXBY. *Excavating Engr.*, **35**, 96–97, 128–30 (1941).—The quarry is located in the mountains west of Maricopa, Calif. It is in a vein 40 ft. thick covering several square miles and is made up of seamy masses and large boulders. Rather light explosive charges are used, and the boulders and other scattered ore are pushed back against the face with a bulldozer. A $^3/_8$-cu. yd. shovel allows sorting out of the pure gypsum by the operator. It loads two trucks, and the driver alternates driving the loaded truck to the crushing plant. At the plant the gypsum is run through a primary and secondary crusher and then over a $^1/_4$-in. screen to take out all fines, the clay impurities also being removed. It is then trucked to the railroad. The finished product must be at least 90% pure gypsum; 4% lime and 6% soluble are allowed. W.D.F.

Elasticity of certain rocks and minerals. FRANCIS BIRCH AND DENNISON BANCROFT. *Amer. Jour. Sci.*, **237** [1] 2 (1939).—The results of dynamical measurements of elastic constants at ordinary pressure and temperature are reported for a few rocks and massive minerals obtained from deep workings of Noranda Mines, Ltd., Ontario, Canada. The elasticity of the massive pyrite and magnetite specimens is discussed in terms of the elastic coefficients of single crystals of these minerals. B.C.R.

Importance of the swelling capacity of clayey binders for molding sands. K. ENDELL, H. REININGER, H. JENSCH, AND P. CSAKI. *Giesserei*, **27** [24] 465–75 (1940); [25] 499–502 (1940).—In natural as well as synthetic foundry sands with clayey constituents, the clay is the binder and the quartz material is the filler. Besides the grain structure of the quartz, the capability of the clayey binder determines all mechanical and technical foundry properties of a molding sand. The investigation showed that bentonites are far superior to kaolinitic clays in regard to binding capacity and strength in both the green and the dried states. A comparison of the American Na bentonite with the German Na bentonite showed that, in all cases, the mechanical strength in the green state is considerably higher in the German bentonite (for the same concentrations), while the strength in the dry state is higher in the American bentonite. Bentonites give values of mechanical strength at low concentrations at which highly plastic kaolinitic clays do not bind at all, and their strengths in the green and dry states at high concentrations are about three times as great. The chemical nature of the exchangeably bound bases of the clays which determines the swelling capacity in water shows the superiority of the adsorp-

tively bound Na ions over the Ca ions. The highest mechanical strengths are obtained with Na bentonites (Geko). With respect to suitability in foundry technique, no fundamental difference exists between natural and synthetic molding sands, but only with synthetic sands is it possible to obtain definite extreme values for gas permeability, shearing and compressive strength in the green state, dry strength, and water content and always to maintain uniformity; undesirable accompanying elements such as iron oxide, lime, etc., can be avoided in synthetic sands, and castings can be cleaned more easily. 25 references. M.H.

Japanese diatomaceous earths and their industrial applications: I. TIHIRO KAWASIMA AND YOITI SIRAKI. *Jour. Japan. Ceram. Assn.*, **49** [577] 14–25 (1941).—The authors studied the physical and chemical properties of diatomaceous earths from the ceramic viewpoint. Samples were collected from numerous diatomite deposits at a number of localities in Japan. A history of the uses of diatomaceous earths is given together with general explanations, especially of a condition of cell division based upon the botanical viewpoint. About five hundred references on diatomaceae and diatomaceous earths are listed. Y.K.

Labradorite-hyperoranite. SAMUEL S. GOLDICK AND GARRETT A. MUILENBURG. *Amer. Jour. Sci.*, **237** [2] 130 (1939).—Feldspar phenocrysts in the diabase porphyry on Mount Devon in the St. Francois Mts., Mo., contain large amounts of potash and for this reason have been referred to as oranite, an intergrowth of potassic and high-lime plagioclase feldspars. Detailed study of this deposit shows that the potash of the large phenocrysts was introduced chiefly during hydrothermal alterations of the dike rock. The original feldspar was a normal labradorite. B.C.R.

Magnesium in Georgia. A. S. FULCRON. *Mfrs. Record*, **110** [2] 19 (1941).—F. describes the deposit of serpentine in Georgia, which is unusual for both its purity and its tonnage. The magnesia content is 36 to 38%. Very little talc, usually accompanying serpentine, is present in this deposit. In addition, 2.5% of a chrome-bearing material, which can be separated readily, is present. B.C.R.

Occurrence of vanadium and molybdenum in clays. V. L. BOSAZZA. *Nature*, **146** [3710] 746 (1940).—B. found small amounts of both vanadium and molybdenum compounds in South African clays. These compounds are not readily segregated unless the clay has been weathered considerably or heated to 1000°C. They can then be extracted with hot water. J.L.G.

Occurrence of willemite. FREDERICK H. POUGH. *Amer. Mineralogist*, **26**, 92–101 (1941).—Willemite is often considered to be characteristic of deposition under high temperatures. Most of the specimens examined indicate a formation through secondary alteration of ore minerals, often under arid climatic conditions. See "Willemite. . .," *Ceram. Abs.*, **20** [4] 104 (1941). W.D.F.

Optical orientation in elongate clastic quartz. RUSSELL G. WAYLAND. *Amer. Jour. Sci.*, **237** [2] 99–109 (1939).—If clastic quartz grains are more resistant to abrasion in certain crystallographic directions, their shape will be an expression of their differential hardness. In a piece of St. Peter sandstone showing elongate parallel grains, the direction of elongation coincides with the direction of the optic axis. Grains of Jordan sandstone were found to be 17.6% longer in the direction of the optic axis than normal thereto. The possible significance of these findings is discussed briefly. B.C.R.

Sediments of Crystal Lake. W. H. TWENHOFEL AND W. A. BROUGHTON. *Amer. Jour. Sci.*, **237** [4] 231 (1939).—An examination of the sediment of Crystal Lake, Vilas County, Wis., showed the presence of 82 species of diatoms, a low calcium and magnesium carbonate content, and a small bacteria count. See "Contribution. . .," this issue, p. 125. B.C.R.

Talc and soapstone. ALLAN F. MATHEWS. *Mineral Ind.*, **48**, 359–64 (1939).—Statistics on the production of talc and soapstone throughout the world are given. In a flotation study, pine oil was found to be most suitable for floating foliated talcs, whereas flotation reagents of the amine type served best for the fibrous talcs. Carbital is a good frother reagent for removing lime from California talcs. Pneumoconiosis may result from the inhalation of pyrophyllite dust. In Germany, a hydraulic cement has been made by heating to redness a mixture of talc and 15% limestone; it may be used as a synthetic stone. B.C.R.

Theory for the concentration and distribution of copper in the earth's crust. CHARLES HENRY WHITE. *Econ. Geol.*, **36** [1] 1 (1941).—Although copper occurs in traces or even determinable amounts throughout the entire crust of the earth, commercial deposits, found in every type of rock, occur only where the crust has been fractured, fissured, or sheared. As the earth cooled to temperatures permitting chemical union of the atoms, the major parts of CuS and others of the less chemically active heavy metals and their associated anions were depressed to a zone below the silicates where they remained until released through fractures in the solid crust. B.C.R.

Thermal conductivity of rocks: I and II. FRANCIS BIRCH AND HARRY CLARK. *Amer. Jour. Sci.*, **238** [8] 529; [9] 613 (1940).—An apparatus for the measurement of absolute thermal conductivity between 0° and 500°C. is described. Results are given for 18 igneous rocks, 7 sedimentary and metamorphic rocks, 3 single crystals, and 4 glasses. At 0°C. the conductivities of all the rocks lie between 0.014 and 0.004 cal./cm. sec. degree; at 200°C., all lie between 0.009 and 0.004. The conductivities of the poorest conductors (glasses and feldspar aggregates) increase with temperature; the conductivities of all of the other materials decrease as the temperature increases. The aggregates having the highest conductivity are the ultrabasic rocks. The results are discussed in the light of theories of heat conduction in crystals. A simple method of computation is shown to account for the conductivities of fresh igneous rocks in terms of their mineral composition and the measured conductivities of approximately monomineral aggregates. B.C.R.

Unusual occurrence of gypsum at Kalgoorlie, Western Australia. REX T. PRIDER. *Amer. Mineralogist*, **25**, 591–605 (1940).—Certain workings in flooded mines apparently existed as air locks, and large crystals of selenite developed on the walls and roof. After consideration of several hypotheses for their origin, the most probable seems to be that these crystals were formed in the short time, several months, in which the mine was being unwatered. W.D.F.

SEPARATE PUBLICATIONS

Annual Report of Mining Division, Fiscal Year 1940. CHARLES F. JACKSON. *U. S. Bur. Mines Repts. Investigations*, No. 3536, 25 pp. Free. R.A.H.

Annual Report of the Nonmetals Division, Fiscal Year 1940. OLIVER C. RALSTON AND JOHN C. CONLEY. *U. S. Bur. Mines Repts. Investigations*, No. 3538, 47 pp. Free.—Reports are given on completed investigations of Pacific Northwest olivine, heat balances of kilns, and intercrystalline cracking of boiler steels; mineral-dressing studies; optical investigations, coal investigations, and the bleaching of iron-stained tripoli; clay investigations; chemical reactions of pozzuolanic materials; new commercial minerals; and publications in press. R.A.H.

Geology of St. John Region, New Brunswick. F. J. ALCOCK. *Geol. Survey, Bur. Geol. & Topography, Mines & Geol. Branch, Dept. Mines & Resources, Canada, Pub.* No. 2447 (1941). 65 pp., 4 maps, 8 illustrations. Price 25¢.—A thick deposit of clay near Brookville is briefly mentioned as of possible future importance but is not otherwise described. G.M.H.

Information for Miners About Coal-Mine Ventilation. A. U. MILLER. *U. S. Bur. Mines Information Circ.*, No. 7137, 4 pp. Free.—M. describes adequate ventilation in mines and makes suggestions for the conduct of both workers and owners of mines maintaining such a ventilating system. R.A.H.

Minerals Yearbook, 1940. U. S. BUREAU OF MINES. Supt. of Documents, Govt. Printing Office, Washington,

D. C. 1514 pp. Price $2.00.—An economic review and statistical summary is presented of the mineral industry of the U. S. in 1939. R.A.H.

Origin, Mineralogy, and Distribution of the Refractory Clays of the United States. A. F. GREAVES-WALKER. *N. C. State Coll. Eng. Expt. Sta. Bull.*, No. 19, 87 pp. (1939). Price 50¢.—Types of fire clays, modes of occurrence, and theories of fire-clay origin, notably those of Lesley, Wheeler, Hopkins, Stevenson, Stout, Galpin, Lovejoy, Hodson, Ross, McQueen, and Allen, are reviewed. The author propounds a new theory which accounts for the origin of all fire clays except in a few special cases, e.g., the sinkhole deposits of Missouri. The essential points of the theory are as follows: (*a*) The basins in which the fire clays were formed and the entering streams were surrounded by a wide fringe of swamp vegetation. (*b*) The feeder streams had low velocities and carried only very fine sediments. (*c*) The climatic conditions were warm and humid. (*d*) The fire clays were formed by soil colloids of variable composition derived from deeply weathered land masses surrounding the basins. (*e*) The soil colloids, moving slowly in swamp-like streams, were leached by CO_2 and organic acids; the larger fragments were dropped in the streams and margins of the basins, and the finer colloids reached the center of the basins. (*f*) Additional leaching took place as the finest particles settled, removing, by solution, silica, iron, alkalis, and alkaline earths. (*g*) Currents from north to south of the Appalachian and Mississippian areas caused by the greater evaporation in the south carried and concentrated the impurities in the southern basins, which accounts for the purer clays of the north. Isolated basins where no currents carried away the impurities account for the impure upper strata of some deposits. (*h*) The buff fired color of fire clays is caused by the combination of the iron oxide and the rutile in the clays during firing, forming pseudobrookite and ilmenite. (*i*) Flint fire clays were formed from the soil colloids present as gels (probably 0.3 micron or less in size), the semiflint fire clays from a mixture of gels and suspensoids, and the plastic fire clays largely from suspensoids almost colloidal in size. Evidence from various sources is submitted to substantiate this theory. The mineralogy of fire clays is discussed. Kaolinite, dickite, halloysite, hydromica, and certain colloids are listed as essential minerals, with quartz, iron compounds, rutile, and tourmaline as principal accessory minerals. The mineralogy of several Pennsylvania, Ohio, Kentucky, Maryland, Missouri, and Georgia clays is discussed. The latter half of the bulletin is devoted to a description of the location, extent, properties, and geology of the refractory clays in 27 states which are the most important in the U. S. The report contains excellent bibliographies for each section. W.W.K.

Petrology and Genesis of the Third Bradford Sand. PAUL D. KRYNINE. *Penna. State Coll. Mineral Ind. Expt. Sta. Bull.*, No. 29, 114 pp. (1940). Price 50¢.—K. describes the application of the methods of sedimentary petrography to the problem of the structural geology of the Third Bradford Sand, which is the chief oil-bearing stratum of the Bradford Field and is actually a medium- to fine-grained graywacke with subordinate siltstone and shale layers. Numerous photomicrographs accompany the petrographic analytical data of numerous samples from drill cores of six wells in the field. An inferred geological history of the formation is given. K. concludes that the Third Bradford Sand is the typical product of one of the graywacke cycles, deposited under deltaic conditions after brief transport which followed violent erosion in a region of rugged relief and high rainfall. The importance of the void structure of the material and its wetting and swelling characteristics is discussed in relation to the water-flooding method of oil recovery. 37 illustrations. V.D.F.

PATENTS

Acid-treating granular materials. J. A. CREW (Ayers Mineral Co.). U. S. 2,233,695, March 4, 1941 (April 4, 1939).—A method of removing undesired ferrous compounds from silica sands, clays, other ceramic materials, and ores.

Precipitating kaolin or clay from finely dispersed colloidal suspensions. RUDOLF SCHMUCKER AND HANS RADLER. Ger. 689,949, March 21, 1940 (Feb. 18, 1938); VI/80*b*. 12.01.—Kaolin or clay in industrial wastes as a colloidal suspension may be precipitated by the addition of alkali-earth chlorides in amounts of 0.1 to 1.5%, depending on the amount of the dry substance contained in the suspension. D.A.B.

Treatment of chromium ores. PITTSBURGH PLATE GLASS CO. Brit. 533,377, Feb. 26, 1941 (Dec. 20, 1938).

Treatment of titanium ores. F. J. CLEVELAND (Pittsburgh Plate Glass Co.). Brit. 533,378 and 533,379, Feb. 26, 1941 (Aug. 29, 1939).

Chemistry and Physics

Applications of the spectrograph to the quantitative analysis of ferrous and nonferrous metals. F. G. BARKER. *Jour. Iron & Steel Inst.* [London], **139** [1] 211–55 (1939).—Brief references are made to the origin of spectroscopy, the principles of refraction, and the early work done in Britain in connection with the application of the spectrograph to metallurgical analysis. A description of a modern quartz spectrograph is given. The technique employed for the preparation of arc spectrograms for the estimation of impurities and minor constituents is described, together with the preparation and use of tables for their evaluation by the internal comparison method. Experimental data show that the use of spark spectrograms with photoelectric methods for their evaluation makes possible the quantitative estimation of several elements in alloy steels simultaneously with an accuracy closely approaching that of chemical analysis. Standard tables and graphs used for the evaluation of spectrograms and the range of steels in which they are applicable are shown. The effects of varying time of exposure, period and temperature of development, age of developer, physical conditions of the sample, and the shapes of the electrodes are described. 28 illustrations. V.D.F.

Determination of cobalt as trioxalatocobaltiate. G. H. CARTLEDGE AND PARKS M. NICHOLS. *Ind. Eng. Chem., Anal. Ed.*, **13** [1] 20–21 (1941).—The authors have developed a new spectrophotometric method of determining cobalt which is much more rapid than the gravimetric or electrolytic procedures. Numerous colorimetric methods are available, but certain of these require time-consuming separations, others are applicable only to minute amounts of cobalt, and others are only fairly accurate. The basis of this procedure is the measurement of the absorption at 605 mμ due to the trioxalatocobaltiate ion, $Co(C_2O_4)_3^{---}$, which is produced by oxidation of a cobaltous solution by lead dioxide in a weakly acid solution of potassium oxalate according to the reaction $2CoSO_4 + 4HC_2H_3O_2 + 7K_2C_2O_4 + PbO_2 \rightarrow 2K_3Co(C_2O_4)_3 + PbC_2O_4 + 4KC_2H_3O_2 + 2K_2SO_4 + 2H_2O$. A small amount of lead remains in solution, presumably as acetate. The trioxalatocobaltiate anion produced has a dark emerald-green color with a maximum absorption at 605 mμ. The intensity of the absorption is used as a measure of the cobalt content. F.G.H.

Determination of silica in calcined alumina. J. R. EDWARDS. *Ind. Eng. Chem., Anal. Ed.*, **13** [2] 70 (1941).—E. has found that silica in calcined alumina may be determined colorimetrically as silicomolybdate in acid solution and that this method is quicker and more accurate than the gravimetric method. It may also be adapted to many estimations of small amounts of silica or silicon. F.G.H.

Determination of surface areas—pigments, carbon blacks, cement, and miscellaneous finely divided or porous materials. P. H. EMMETT AND THOMAS DEWITT. *Ind. Eng. Chem., Anal. Ed.*, **13** [1] 28–33 (1941).—During the

last few years a method for measuring surface areas of iron synthetic ammonia catalysts by means of low-temperature adsorption has been developed and extended in its application to other metallic catalysts and to a variety of non-metallic adsorbents including soils, powdered bacteria, silica gel, chromium oxide gel, potassium chloride, anhydrous and hydrated copper sulfate, and activated charcoal. As the method is comparatively simple and rapid in operation and appeared from previous work to be widely applicable, it seemed worth while to attempt to utilize it in measuring the surface area of a number of industrially important finely divided materials. Results obtained on a series of carbon blacks, zinc oxide, pigments, titanium dioxide, barium sulfate, zirconium silicate, graphite, cement, lithopone, paper, and cuprene are summarized. The surface areas are obtained by selecting, on each experimental adsorption isotherm of a gas such as nitrogen, the point corresponding to a monolayer. A multiplication of the number of molecules required to form the single layer by the average area occupied by each adsorbed molecule yields a numerical value for the absolute area of a given weight of the absorbent. Illustrated. F.G.H.

Development of a new method for measuring particle-size distribution in colloidal systems. E. A. Hauser and C. E. Reed. *Jour. Phys. Chem.*, **40**, 1169 (1936).—A new method for making particle-size fractionations and for measuring particle-size distribution curves of colloidal systems is described. A supercentrifuge is used, and the theory of the method has been developed for supercentrifuges already on the market. Improvements in the method, the best available at the present time, will probably come with improvements in the design of the supercentrifuge. See "Particle. . .," *Ceram. Abs.*, **19** [10] 240 (1940). R.A.G.

Effect of ammonium chloride on the thermal change of ceramic raw materials. Tosiyosi Yamauti and Kohei Konisi. *Jour. Japan. Ceram. Assn.*, **49** [577] 9–13 (1941). —Y. discovered in his previous investigation that NH_4Cl is very effective in inverting quartz to tridymite. In this report, the authors studied the effect of NH_4Cl on ceramic raw materials, viz., Mituisi Roseki (pyrophyllite rock, raw material for firebrick), Chojo fire clay (high aluminous flint clay from North China), talc, magnesium hydroxide, Chosen kaolin, limestone, fluorite, and feldspar. NH_4Cl (5, 3, 1, and 0%) was added to each sample, and the change in weight was determined by a thermobalance; the thermal analysis was also studied. The temperatures of dehydration or dissociation of magnesium hydroxide, limestone, talc, Roseki, Chosen kaolin, and Chojo fire clay were decreased considerably by the addition of NH_4Cl, but no effect was found on fluorite and feldspar. A well-polished silica glass plate was heated at 400°, 500°, 600°, 700°, and 800°C. in HCl gas, NH_3 gas, and (HCl + NH_3) gas. After being cooled, the cristobalite formation was examined by a microscope. HCl gas is a very effective mineralizer, but NH_3 gas is not so effective. It is not clear whether this reaction is caused by hydrogen or chlorine, but the authors consider chlorine to be effective. Y.K.

Fluidity of low-melting mixtures of metal oxides, significant for the clinkering of firebrick. K. Endell and G. Brinkmann. *Ber. Deut. Keram. Ges.*, **20** [12] 493–507 (1939).—In a large number of 3-phase systems of metal oxides which are of importance in the formation of metallurgical slags and for the clinkering of firebrick, the lowest-melting mixtures were tested in platinum, under perfect conditions, for their change in viscosity with temperature. The results in the systems $CaO–Al_2O_3–SiO_2$, $MgO–Al_2O_3–SiO_2$, and $CaO–FeO(Fe_2O_3)–SiO_2$ show clearly in all cases an increase in viscosity with increasing content of silica and clay. The lime-iron-silica melts are by far the most fluid. An attempt was made to find the relation between the structure of the silicate solutions and their viscosity. A clear relation was found between the viscosity at 1500°C. and the ratio $CaO/SiO_2 + Al_2O_3$. For the special case of the basic and acid blast-furnace slags, the viscosity at 1400°C. can be calculated from the viscosity index, i.e., from the ratio of oxides which lower viscosity to oxides which raise it. The influence of radius of ions on viscosity is given. Previous tests showed that, in blast-furnace slags, SiO_2 and Al_2O_3 always increase the viscosity. It is now found that CaO, MgO, FeO, MnO, TiO, and alkalis lower the viscosity. The separation of the lattice by the cations is the greater, the more cations there are, the smaller the ion radius, or the greater their valence. By this loosening of the lattice, the melts always become more fluid. Al has a tendency to increase viscosity, but on account of its field of force it tends to break down the SiO_4 tetrahedrons and thus decrease the viscosity. Both effects act together in a manner yet unknown. Practical consequences regarding the prediction of viscosity from the chemical composition and the behavior of firebrick in regard to clinkering are based on the viscosity relations at high temperatures. W.H.H.

Fluorspar analysis. E. O. Primbsch. *Emailwaren-Ind.*, **17** [41–42] 107–108 (1940).—In fluorspar (CaF_2), calcium and fluorine are the principal ingredients to be determined, although the high silica content as the chief impurity is also important. Other impurities are $CaCO_3$, Al_2O_3, $CaSO_4$, Fe_2O_3 and manganese, and barium compounds. The loss on ignition is first determined. One gram of the sample is placed in a platinum crucible over the full flame of a Bunsen burner and calcined to constant weight; there is no danger of much fluorine being lost. After the loss of weight is determined, the same specimen is used for determining the SiO_2. It is evaporated three times with about 3 to 4 cc. of HF to dispel all the SiO_2 as SiF_4, then heated to redness, cooled in an exsiccator, and weighed. The loss in weight is the SiO_2 content. The quantitative determination of $CaCO_3$ is not necessary unless the presence of CO_2 is found by qualitative test in a test tube. The test is as follows: 1 gm. of fluorspar is warmed with 50 cc. of $N/10$ HCl solution, preferably in a 250-cc. flask with a perforated rubber stopper. The temperature should not be high enough to expel steam (P. recommends attaching a reflux condenser). A large part of the sample remains undissolved, and it is filtered after about 15 min., washed, and titrated back with $N/10$ solution of caustic soda. The difference between the HCl used and the caustic soda solution used is the consumption of $N/10$ HCl; 1 cc. of the used $N/10$ HCl = 5.00 mgm. $CaCO_3$. The residue from the determination of the SiO_2 consists of more or less pure CaF_2, according to the quantity of impurities. It is evaporated with concentrated H_2SO_4, heated slightly to redness, and weighed as calcium sulfate. The factor for reducing to CaF_2 is 0.5735. To determine other impurities, sufficient HCl is added to dissolve the greater part, the undissolved portion being barium sulfate, which is filtered. The filtrate is made ammoniacal and treated with a few drops of hydrogen superoxide to precipitate aluminum, iron, and manganese as hydroxides. They are determined together by filtering through an ash-free filter and washing; the filter is dried and heated to redness. The weight of the oxides found is subtracted from that of the CaF_2 content calculated from the sulfate. After the method described, there is no direct method of determining the fluorine exactly and quickly in an industrial laboratory; a simple method which is sufficiently exact for industrial purposes, however, consists in mixing 1 gm. of the sample with the same quantity of finely pulverized SiO_2 and placing it in a tared 50-cc. measuring flask with a glass stopper; 10 to 15 cc. of concentrated H_2SO_4 is added to the mixture, the glass stopper is put in, and the whole is weighed quickly. The stopper is then removed, and the flask is shaken to mix the contents well and then carefully heated, but not enough to expel the H_2SO_4 vapors. It is shaken at intervals, heated to constant weight, and left to cool a half hour with the stopper on; it is then weighed and heated again for a half hour. When the constant weight is determined after repeated weighing, or if the decrease in weight is negligible, the test is completed. The fluorine content is calculated from the loss in weight which consists of SiF_4; the factor is 0.73. See "Analytical. . . ," *Ceram. Abs.*, **20** [4] 83 (1941); "Testing. . .," this issue, p. 129. M.V.C.

Linear thermal expansion of quartz (rock crystal). Joseph L. Rosenholtz and Dudley T. Smith. *Amer.*

Mineralogist, **26**, 103–109 (1941).—Results with a new apparatus are given. Quartz was used to test its accuracy. A combination of a Chevenard differential dilatometer and a capillary cell was used. Expansion of the specimen moved a diaphragm which moved the mercury in a capillary tube; the expansion was also read by a lever system and an Ames dial. The Ames dial was needed to calibrate the capillary readings, and the capillary was necessary to measure very small expansions. Six sections were cut perpendicular to the *c* axis, and three each were measured parallel to the first and second order crystallographic directions. As these were the same, all were averaged. The results checked the most probable values as given by Sosman, except at 573° and at 1000°. Four sections were cut parallel to the principal axis. These agreed with Sosman's values up to 500° but diverged afterward. The critical point for the alpha-beta inversion is 573.1 ± 0.5°C. Another change was noted at 872° on all perpendicular sections but on only one of the parallel sections. This probably represents the quartz-tridymite inversion. W.D.F.

Microphotometer for spectrochemical analysis. Edward M. Thorndike. *Ind. Eng. Chem., Anal. Ed.*, **13** [1] 66–67 (1941).—Details of the construction, operation, and performance are given. Illustrated. F.G.H.

Polarographic determination of nickel and cobalt—simultaneous determination in presence of iron, copper, chromium, and manganese and determination of small amounts of nickel in cobalt compounds. James J. Lingane and Herbert Kerlinger. *Ind. Eng. Chem., Anal. Ed.*, **13** [2] 77–80 (1941).—The authors describe conditions under which nickel and cobalt can be determined simultaneously by the polarographic technique with the dropping mercury electrode. Heretofore, an ammoniacal supporting electrolyte has been recommended for the simultaneous polarographic determination of nickel and cobalt. The degree of separation of the two waves in an ammoniacal medium, however, is none too good, and accurate determination of the nickel is not possible when a large amount of cobalt is present. An excellent separation of the nickel and cobalt waves is obtained in supporting electrolytes containing thiocyanate or pyridine. The use of these supporting electrolytes makes possible the rapid determination of small amounts of nickel present as an impurity in cobalt compounds. Illustrated. F.G.H.

Rapid determination of antimony, tin, and bismuth. Silve Kallmann and Frank Pristera. *Ind. Eng. Chem., Anal. Ed.*, **13** [1] 8–11 (1941).—New short methods for the accurate determination of antimony, tin, and bismuth in metals, alloys, and ores are described. Antimony, tin, and bismuth are coprecipitated with manganese dioxide formed by the reaction of manganese ion and potassium permanganate in hot dilute nitric or sulfuric acid solution. For the determination of antimony, tin, or both, the manganese dioxide precipitate is fumed with sulfuric acid, potassium hydrogen sulfate, and ammonium sulfate. To determine antimony, the solution is diluted with sulfur dioxide water, boiled down with hydrochloric acid, diluted, and titrated with potassium permanganate or potassium bromate. Tin is determined by reducing, with nickel and hydrochloric acid, the solution containing the fumed manganese dioxide precipitate, or the solution that remains after the titration of the antimony, and finally titrating with standard iodine solution. For the determination of bismuth, the manganese dioxide precipitate is dissolved in dilute nitric acid and hydrogen peroxide. The bismuth is separated with the help of zinc oxide, which precipitates the bismuth as basic nitrate. This, in turn, is dissolved in nitric acid from which the bismuth is finally precipitated and weighed as bismuth oxychloride. F.G.H.

Rapid method for determining ferric and ferrous iron. John O. Percival. *Ind. Eng. Chem., Anal. Ed.*, **13** [2] 71–72 (1941).—Using precipitated copper as a reducing agent, determinations of ferrous and ferric iron are carried out in less than 10 min., with a minimum of equipment and skill, with common stable reagents, in the presence of large amounts of cupric, ferrous, manganous, zinc, nickel, and chromic ions, and with a precision and accuracy of about 3 parts per thousand. F.G.H.

Reactions in melts. Hermann Lux. *Naturwissenschaften*, **28** [6] 92 (1940).—Using precious metal electrodes (gold), L. investigated the character of several oxides. B_2O_3 and $NaPO_3$ were highly acid; Na_2SO_4, Li_2SO_4, and $Na_2B_4O_7$ were neutral; and Na_2CO_3, Li_2CO_3, and Na_3BO_3 were strongly alkaline. Experiments were made at 950°C. with Na_2SO_4-K_2SO_4 eutectic as the solvent. It was found that the peroxides, carbonates, nitrates, nitrites, etc., were identical for the same base. These salts of sodium, the carbonates of lithium, barium, strontium, and calcium, and CaO all had the same potential as Na_2O. MgO, BeO, Al_2O_3, La_2O_3, and ZnO were found insoluble. Reactions taking place between alkali oxides and Al_2O_3, SiO_2, TiO_2, ZrO_2, $NaPO_3$, and $NaBO_2$ were investigated. The method was satisfactory for any degree of dilution. At medium concentrations of Na_2O, SiO_2 and TiO_2 formed orthosilicates and titanates, respectively. J.M.N.

Recrystallization of alumina. Eugen Ryschkewitsch. *Ber. Deut. Keram. Ges.*, **20** [11] 477–84 (1939).—Thirteen photographs taken with the aid of the large polarizing microscope of R. Fuess show samples of alumina of different purity, the growth of crystals, and gas inclusions within the crystals. Such knowledge of crystal size and grouping promises a considerable improvement in the technological characteristics of sintered alumina. W.H.H.

Testing orthoboric acid and borax. E. O. Primbsch. *Emailwaren-Ind.*, **17** [47–48] 125–26 (1940).—A qualitative test is sufficient for determining the impurities of orthoboric acid (H_3BO_3). The test is as follows: 10 gm. are dissolved in 15 cc. of hot water, and, if any insoluble residue remains, it should be filtered through a filter crucible with a suction pump, washed, dried at 110° in a drier, and weighed. It should amount to less than 0.2%. The filtrate is tested with 2% silver nitrate solution for chloride and with 5% barium chloride solution for sulfate. Little clouding and no precipitation should occur. A refined boric acid must contain 98 to 99% H_3BO_3, and the crude product must contain 80%. A volumetric analysis is more suitable than the gravimetric analysis because boric acid can be titrated in the presence of mannite or glycerin with soda lye and phenolphthalein as indicators. The test follows: 0.5 gm. boric acid is weighed in a 250-cc. Erlenmeyer flask and dissolved in hot water. The solution is treated with 3 drops of phenolphthalein as indicator and 2 to 3 cc. of saturated mannite solution and titrated with *N*/10 NaOH. Titration is ended when the red coloring no longer disappears as more mannite is added. The last color change is so sharp that no more than 2 drops of NaOH is necessary. One cubic centimeter of *N*/10 NaOH corresponds to 6.184 mgm. H_3BO_3. As about 80 to 81 cc. *N*/10 NaOH are required for 0.5 gm. H_3BO_3, it is advisable to titrate with *N*/5 NaOH in laboratories which do not work with titrating apparatus, so that the burette need be filled only once. For the borax analysis, practically the same treatment can be used but the determination of Na_2O is important. It is as follows: 0.5 gm. borax is weighed in a 400-cc. Erlenmeyer flask and dissolved with water; a few drops of methyl orange are added as indicator, and the solution is titrated with *N*/10 HCl until the yellow coloring turns red. One cubic centimeter of *N*/10 HCl corresponds to 3.07 mgm. Na_2O. Details of the tests are discussed. The determination of B_2O_3 will be published later. See "Analytical. . . ," *Ceram. Abs.*, **20** [4] 83 (1941); "Fluorspar. . . ," this issue, p. 128. M.V.C.

Volumetric determination of iron and aluminum in cement with 8-hydroxyquinoline. Leo Kampf. *Ind. Eng. Chem., Anal. Ed.*, **13** [2] 72–73 (1941). F.G.H.

Water glass. Bruno Schweig. *Glass*, **18** [1] 8 (1941).—S. discusses the history and composition of water glass, the formula of which may be represented by $Me_2O \cdot nSiO_2$, where Me represents one or more alkali metals and *n* indicates the molecular ratio of the SiO_2 to the alkali. The factor *n* may be fractional and, for sodium silicates, may vary from 1.2 to 4. B.C.R.

X-ray diffraction studies in the system CuO–Fe_2O_3. W. O. Milligan and James Holmes. *Jour. Amer.*

Chem. Soc., **63** [1] 149–50 (1941).—Radiograms of mixtures of cupric and ferric oxides precipitated together at 25°C. show no indication of the formation of cupric ferrite. The results are similar for samples aged by boiling under water for 24 hr., except that sharper X-ray diffraction patterns of α-ferric oxide and cupric oxide are obtained. These observations are in agreement with the results of Wartmann and Thompson and of Holgersson but are contrary to the results of Forestier and Longuet. It is concluded from X-ray diffraction patterns of the samples heated to 1000°C. that $CuFe_2O_4$ is the only compound formed in the system CuO–Fe_2O_3. Illustrated. F.G.H.

PATENTS

Making calcium metaphosphate. R. L. COPSON. U. S. 2,233,401, March 4, 1941 (Nov. 9, 1939).

Making zirconium oxide. C. J. KINZIE AND D. S. HAKE (Titanium Alloy Mfg. Co.). U. S. 21,726, Feb. 25, 1941 (Oct. 11, 1940); reissue of original 2,168,603, Aug. 8, 1939 (Sept. 2, 1936).

Manufacture of anhydrous beryllium fluoride free from oxide. CARLO ADAMOLI (Perosa Corp). U. S. 2,233,465, March 4, 1941 (Jan. 7, 1939).—A process for the manufacture of anhydrous beryllium fluoride free from oxide consists in causing a compound of the group consisting of ammonium fluoride and ammonium acid fluoride to act *in vacuo* and in the hot state on an oxygenated beryllium compound belonging to the group consisting of the oxide, the hydrate, and the carbonate of beryllium in a dry state, the proportion of ammonium fluoride which is used substantially corresponding to that which is theoretically necessary for forming only beryllium fluoride.

Preparation of pure titanium oxide. F. C. VERDUIN (Sherwin-Williams Co.). U. S. 2,232,817, Feb. 25, 1941 (Oct. 20, 1938).

Production of titanium pigments. NATIONAL TITANIUM PIGMENTS, LTD. (Verein für Chemische und Metallurgische Produktion). Brit. 533,227, Feb. 19, 1941 (Aug. 5, 1939).

Titanium pigment and method of producing. D. H. DAWSON (E. I. du Pont de Nemours & Co.). U. S. 2,232,168, Feb. 18, 1941 (May 19, 1939).—A process for producing an improved pigment comprises preparing a suspension having a pH between about 5 and 9, the suspension containing a titanium pigment and hydrated oxides of aluminum and chromium, and thereafter separating the resulting pigment and drying.

Water-resistant alkali silicate composition. C. H. HUMPHRIES (Insolna Corp.). U. S. 2,234,646, March 11, 1941 (Aug. 15, 1938).—A water-resistant alkali silicate coating composition consists essentially of water glass, water, formaldehyde, a 20% sodium aluminate solution, and sodium abietate in substantially the proportions of about ½ gal. water glass, ½ gal. water, 1 to 6 oz. formaldehyde, ½ to 1½ oz. sodium aluminate solution, and 1 to 3 oz. sodium abietate.

General

Correlation coefficient between the basophilic aggregation test and lead in urine. S. F. MEEK, G. R. COLLINS, AND G. C. HARROLD. *Jour. Ind. Hyg. & Toxicol.*, **22**, 401–407 (Nov., 1940).—A rapid and satisfactory method for the preparation of urine specimens for lead analysis is described in detail. A urinary lead excretion level of 0.05 mgm. per liter was found for nonexposed persons employed in lead-using industries. Instantaneous and 8-hr. specimens of urine correlated sufficiently well with 24-hr. specimens to serve as an index of lead absorption as reliable as that possible with one 24-hr. sample. Three random instantaneous samples taken within a week provided a reasonable index of absorption. Good correlation has been established between the basophilic aggregation test and values of lead in urine; a high correlation coefficient (0.69) was found in the lead-absorption range. No correlation was obtained in cases of chronic lead poisoning examined after long exposure. F.S.M.

Determination of minute amounts of lead in urine. J. E. KENCH. *Biochem. Jour.*, **34**, 1245–47 (Sept., 1940).—K. describes the dithizone extraction of urine residues for lead. Control urine sample of adults yielded 0.038 to 0.08 mgm. of lead per liter, with an average of 0.057, by this method. Workers exposed to lead showed 0.1 to 0.35 mgm. of lead per liter of urine. No figures are given for the concentrations to which these workers were exposed. F.S.M.

Dust counting—a simplified technique. H. R. OHLHEISER AND L. B. LAWRENCE. *Jour. Ind. Hyg. & Toxicol.*, **22**, 472–76 (Dec., 1940).—Various substitutes proposed for the Sedgwick-Rafter cell for dust counting were found to possess certain advantages. The Levy-Hausser blood-counting chamber has a depth of 0.1 mm., and its cover has coarse and fine square rulings. A series of dust counts on impinger samples with this instrument showed it to have the following advantages over the ordinary method employing the Sedgwick-Rafter cell and Whipple disk: (1) the equipment is simpler and is easily procurable; (2) no calibration is necessary; (3) the factor is independent of magnification or optical equipment; (4) the equipment is more easily and quickly cleaned, filled, and manipulated; (5) less dilution is required; (6) only a few minutes is required for settling before counting; (7) the area being counted can be kept under the center of the lens system; (8) the error due to dust on the ocular disk is eliminated; and (9) it is possible to examine a given field for contaminating dust particles, fill the cell, and then count the same area. Using light field and the same magnification, the counts by the two methods agreed substantially. Full directions for the use of the blood-counting chamber are given. F.S.M.

"Finis" to lead poisoning. H. J. ROESCH. *Factory Management & Maintenance*, **98** [11] 80–82, 152–53 (1940).—R. describes the method by which an automobile body manufacturer controlled lead-poisoning hazards so that there have been no cases of lead poisoning in the plant in more than three years. Measures adopted included two respirators for each man, special washrooms and washing techniques, the prohibiting of eating in working departments, the removal of lead dust at the source by means of vacuum cleaners and a "push-pull" system of ventilation, monthly blood tests, grinding on soldered surfaces only in exhaust hoods, and making dust counts on plant air. Illustrated. J.L.G.

Health in industry. R. B. ROBSON. *Amer. Jour. Pub. Health*, **31** [2] 162 (1941).—R. discusses the value of a full-time nurse for industries having 500 or less employees. Health conditions both at home and at work are inspected. In one case cited, the number of days lost through sickness and accident per employee was reduced about ⅓ after the services of a nurse were obtained. B.C.R.

Carl George Hilgenberg. ANON. *Bull. Amer. Ceram. Soc.*, **20** [3] 109–10 (1941).

History of the Carr-Lowrey Glass Co. ANON. *Bull. Amer. Ceram. Soc.*, **20** [3] 110–12 (1941).

Industrial cleansing of the hands and the prevention of skin diseases. H. HEBESTREIT. *Zentr. Gewerbehyg. & Unfallverhüt.*, **16**, 268–72 (Dec., 1939).—H. reports on the prevention of occupational diseases, dealing particularly with the washing process and with skin injuries from washing. Soap as generally used is responsible for some of the injuries. H. discusses soaps of various contents, hard, soft, and mineral waters, and the sources and results of alkaline reactions in or upon the skin and emphasizes the importance of preserving the normal pH value (4 to 6) of the skin. The relation between harmful processes of skin chemistry and the development of water eczema among workers is pointed out. Why and how the skin swells under mistaken methods of washing it and how dirt is often driven irrecoverably into the deeper skin structure are carefully explained. The advantages of washing the skin with soap substitutes, such as Praecutan or Satina,

are given, and the components of the substitutes are revealed. Experiments on the washing of human skin show that alkaline reactions heat or inflame it into disordered functioning and even cause surface destruction. The several cleansing media for the skin and hands and their various components are reviewed and evaluated. Such media should preserve the skin from inflammation, should be inherently good for it, and should protect the skin for a long time. Protective coverage of skin surfaces unavoidably exposed to injurious processes can be obtained by the use of the finest kinds of clay and certain colloidal proteins, but even these have inevitable disadvantages. H. states that callused, horny, and misshapen hands of industrial workers are by no means inevitable, as the principles and procedure of intelligent care of the skin, including its normal preservation, are beginning to be understood and put into practice in industry. K.R.

Industrial dermatoses. W. E. Obetz. *Ohio Ind. Commission Monitor*, **13**, 179–82 (Dec., 1940).—O. discusses (1) the careful selection of employees to be placed in occupations where skin disease is likely to develop; (2) the maintenance of good housekeeping and adequate ventilation throughout the plant; and (3) the benefits to be derived from personal cleanliness on the part of all employees as a prophylactic measure in the prevention of skin disease. F.S.M.

Industrial hygienist. Warren A. Cook. *Ind. Med.*, **9** [12] 595–99 (1940).—C. attempts to outline briefly the procedures at the disposal of the industrial hygienist in combating occupational disease hazards and in furthering industrial health. K.R.

Industrial medicine and industrial hygiene. K. E. Markuson. *Ind. Med.*, **9** [5] 261–64 (1940).—The life span of an individual worker was estimated in 1929 by Louis Dublin for the Metropolitan Life Insurance Company as being seven years less than that of the nonindustrial. Before 1936 only 3 states maintained industrial hygiene bureaus; by 1940, 26 states and a number of cities had established them. A recent reinforcement of the needs of the small employer is described. Michigan has established a Bureau of Industrial Hygiene whose services are available without cost to any firm or physician in the state. Needed assistance may be obtained on request to the State Bureau of Industrial Hygiene or to any of the local bureaus located in the health departments of Detroit, Grand Rapids, Flint, and Saginaw. M. is the director of this bureau, which is part of the Michigan Department of Health, and is also a director of the Detroit Health Department. K.R.

Industrial procedure for occupational disease control. H. R. Ohlheiser. *Ind. Med.* [Ind. Hyg. Sect.], **9** [7] 45–48 (1940). K.R.

Industrial research in 1940—advances in the United States and other countries. William A. Hamor. *News Ed.* (Amer. Chem. Soc.), **19** [1] 1–16; [2] 57–72 (1941).—Developments in all branches of the ceramic field are briefly reviewed. Illustrated. F.G.H.

Lead poisoning. E. L. Belknap. *Ind. Med.*, **9** [10] 505–509 (1940).—Any single criterion or finding will not validate a diagnosis any more than will a mere enumeration of results from laboratory tests or the details of a complete clinical picture. A reliable diagnosis must integrate all such factors. As a diagnostic preliminary, the great difference between lead absorption and lead intoxication must be appreciated. Laboratory findings, such as lead found in the blood or in the urine, are merely evidences of lead absorption. Such lead enters the bloodstream directly, circulates in it, and is distributed into other bodily tissues, including the bones. Lead intoxication, however, is lead poisoning from lead previously absorbed, which, taken in small amounts, was not necessarily harmful and frequently was not disabling. By reduction of further exposures through protective engineering devices, lead absorption may be prevented from developing into actual lead intoxication. A lead line on the gums opposite carious teeth or on gums inflamed by pyorrhea is evidence of lead poisoning. The absence of a lead line, however, does not exclude the possibility of lead absorption in an infected oral cavity but usually indicates no clinically serious presence of circulating lead. Laboratory studies also reveal lead absorption. B. discriminates between and evaluates the several methods at present used. He explains why lead findings in the urine have greater clinical significance than the lead findings in the blood. The urinary response is more prompt and definite than the blood response. High levels in both blood and urine, however, are consistent with good health in lead workers over a period of years. The Wright stain, a study of stippled red cells in the blood smear, is discussed as a means of determining lead absorption, and the procedure and results are given. When lead absorption becomes an illness, as in lead colic, lead palsy, or in serious cerebral involvement, lead intoxication, or true lead poisoning, has begun. All three conditions are acute. Each is evaluated. The cerebral type of injury is the only fatal one. Due to even ordinary precautions now being taken against lead absorption, the "dramatic" characteristics resulting from exposure to tetraethyl lead, along with other lead encephalopathies, have been practically eliminated from American industry. Chronic lead poisoning is not verified, and reasons for this are given. The lead in and of itself is not a tissue poisoning. Deleterious effects depend upon the lead concentrations in the bloodstream. No fibrosis due to lead is set up in the respiratory tract as in the case of silica inhalation. Even in the most concentrated lead exposures, as sustained by lead smelters, in the paint-grinding trades, or in the storage battery industry, there is no tuberculosis increase. Adult lungs, liver, or kidneys are apparently not damaged by the amounts of lead now circulating in those organs in ordinary industry, and increased lead absorption does not increase ulcer of the stomach or high blood pressure. Blood-forming centers in the bones are not impaired by lead deposits therein. All such factors seem to prove clinically that which has previously been shown experimentally, viz., that there is a normal lead metabolism due to excretion through the bile into the feces and the urine. Workers removed from lead exposures for one or two years practically never develop lead intoxication. The body seems able to handle small amounts of circulating lead, showing that the lead metabolism may exist without symptoms or appreciable body damage. B. discusses theoretically where, when, and how this metabolism may be deranged, causing the development of disabling or disastrous symptoms. 14 references. K.R.

Lessons from the history of lead poisoning—a review of international experience. Ludwig Teleky. *Ind. Med.* [Ind. Hyg. Sect.], **9** [1] 17–20 (1940).—Lead poisoning was known as far back as 1500 years ago, when it was caused largely by ingestion of lead and its compounds with food or as medicine. Hippocrates described it as an occupational disease only in the smelting of metals. T. suggests that it was not mentioned in connection with other occupations because the worker did not continue uninterruptedly at one operation over any length of time, with the exception of the slaves in the mines and in smelting operations. A really standard work on plumbism appeared only 100 years ago; this was a two-volume book of 1100 pp. by Tanquerel des Planches entitled Treatise upon Diseases Caused by Lead, or Saturnism (Traite des maladies de plomb), Paris, 1839. In the book, 1213 cases of lead colic, 752 cases of arthralgia, 146 cases of paralyses from lead, 72 encephalopathies, and other types of lead-caused diseases are discussed. This work continues to be the best and the most detailed clinical picture of lead poisoning in existence. One third of the lead colic patients came from white lead manufacturing plants, another third was affected through the use of white lead and its compounds, and the remainder included 54 potters, 52 type-founders, and 12 compositors and printers. T. points out the varying results of the evolution of lead industrial processes. In small potteries where ground lead ore (galena), which is practically insoluble in body fluids, was used for glazing, no poisoning followed. With use of red lead, a very poisonous form, the technical processes became more highly developed. In the small plants the men would turn the pots for some weeks and then conduct glazing and firing

operations for a few days; the danger was reduced by this alternation. If the workshop develops into a factory, however, one group of workers is continually kept at glazing operations; the exposure to the lead hazard is thus continuous, and the danger is very great. In England in 1900 the danger in the pottery industry was at its maximum, 210 cases being reported in that year. In 1937 only 5 cases were reported. K.R.

Noise and vibration control. G. H. FERGUSON. *Can. Pub. Health Jour.*, **31**, 613–18 (Dec., 1940).—F. discusses noise and vibration in industry, their effects on health, and various methods of control. Legislation and the extension of compensation to include diseases caused by noise are believed to be efficient ways of eliminating avoidable industrial noises. Workers should be carefully selected in cases where noise is unavoidable. The protection of hearing by the application of prophylactic measures, rest pauses, etc., is discussed. F.S.M.

Progress in ceramics since 1926. W. FUNK. *Angew. Chem.*, **53** [21–22] 221–27 (1940).—Clay research in the last decade has developed accurate methods of determining particle sizes of clays that will allow systematic classification of clay types. The chief clay minerals are kaolinite, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$, and montmorillonite, $Al_2O_3 \cdot 4SiO_2 \cdot H_2O, mH_2O$, with air-dry montmorillonite (m) lying between 4 and 5. Valuable results have been obtained in regard to the adsorptive properties of clays and base exchange. American research work on pH values and on Na_2CO_3 as a means of changing the pH has resulted in greater density and higher fired strength of ceramic goods. Bentonite in ceramic masses has been found to be a suitable substitute for highly plastic clays. The castability of clay slips is favorably influenced by alkali-soluble humic substances. In clay preparation, improvements have been achieved with regard to the magnetic separation of iron particles by means of rapidly vibrating fine-mesh screens. In Germany, filter cloth has lately been replaced by a new type of filter tile, the filtration speed of which is two to three times higher than that of cloth. The deairing of clay masses, originally applied to heavy-clay products only, is now being applied to fine ceramic ware. Much study has been devoted to the firing process, i.e., firing temperatures, firing period, and kiln atmosphere; the ratio of the vitrifying and crystal substance to the volume of the pores determines the properties of the goods. Results of tests show the possibility of firing chinaware and steatite at lower temperatures without increasing the firing period over a certain limit. Electrically heated kilns have been used in the ceramic industry since 1934; their advantage lies in the fact that the firing process can be regulated at will. The high-frequency technique uses dielectric masses containing titanium dioxide for insulators and condensers; formerly steatite was used exclusively. In the refractory industry, important developments have been achieved in the field of special high-quality refractories. Magnesite brick resisting thermal shock are manufactured without loss of other properties. Zircon refractories are widely used for furnace linings. Sillimanite, silicon carbide, and corundum are used where resistance to extreme temperatures is required. An extensive bibliography is included. F.E.S.

Pumping of granular solids in fluid suspension. HERBERT CHATLEY. *Engineering*, **149**, 230–31 (1940).—The low efficiency usually obtained is attributed largely to bends and inlets or to the incorrect proportioning of fluid and solid. When solids are not sustained in the stream, they can be propelled horizontally only by rolling, requiring a much greater expenditure of energy. B.C.R.

Rachitogenic effect of beryllium carbonate. L. BUSINCO. *Rass. Med. Applicata Lavoro*, **11**, 417–42 (1940).—Doses of beryllium carbonate varying from 0.150 to 0.037 gm. were given daily to rats for periods up to 48 days. The animals lost weight and were less active, and changes in the vertebra, ribs, and the epiphyses of the tibia and femur were observed by means of the roentgenograph. Histological examination showed typical rachitic changes in many epiphyses; these were not improved by the administration of cod-liver oil and other antirachitic substances. A similar effect was seen in the fetus. Beryllium and its salts are made in Italian factories, and the beryllium carbonate used in the experiments came from two factories. That from one source was noticeably more toxic than that from the other. Illustrated by roentgenograms and photomicrographs. F.S.M.

Response of peritoneal tissue to industrial dusts. J. W. MILLER AND R. R. SAYERS. *U. S. Pub. Health Repts.*, **56** [7] 264–72 (1941).—Several previous reports upon the reaction of peritoneal tissue to injected dusts are referred to. Such biological response is produced for the purpose of predicting the pneumoconiosis-producing potentialities of industrial dust. The experimental procedure upon guinea pigs as now practiced is given briefly. No cases of pneumoconiosis have been reported and confirmed among workers exposed solely to dusts of the absorptive group; all the dusts in the proliferative group, however, are known to produce a nodular, pulmonary fibrosis (silicosis). Pneumoconioses caused by dusts of the inert group (asbestos, anthracite mine, bisque ware, mica, pyrophyllite, and talc dust) have been reported, following X-ray examinations of industrial workers. The interpretation of the response of a dust injected into the peritoneal tissue of animals can be used as an index to determine the potential harmfulness of an industrial dust. Ten industrial dusts causing an absorptive reaction examined by this method are listed, together with their chemical composition and other pertinent identifying data. Among the more familiar substances in this list are calcite, gypsum, various limestones, and Portland cement. Thirteen dusts causing a proliferative reaction, among which are five kinds of quartz, quartz-sericite, and tripoli, were also examined. Of this group, those of special ceramic interest include (1) bisque ware, a ground semivitreous pottery bisque fired at a relatively low temperature, which shows on chemical analysis 72% silica and on petrographic examination 40 to 50% quartz, the remainder being semifused clay and feldspar; (2) green ware, a ground semivitreous pottery ware, which shows on chemical examination 69% silica and on petrographic examination about 50% quartz, about 15% feldspar, and about 35% clay; another sample of greenware showed higher quartz and less feldspar and clay in about the same amount; (3) porcelain enamel frit which shows on chemical analysis 35 to 50% silica, the remainder being oxides of antimony, zinc, aluminum, and calcium. Twenty-seven dusts causing an inert reaction include aluminum, three types of asbestos, two types of anthracite coal, two types of bituminous coal, calcium phosphate, chromite, diamond dust, feldspar, four types of fuller's earth, glass wool, hematite, kaolin, mica, sericite, two soapstones, shale, and talc. Another bisque ware in the group, fired at a relatively high temperature, has about 30 to 40% quartz; the particles are wholly or partly covered by the glass phase, absent in the semivitreous; kaolin of this group shows, petrographically, predominantly china clay and hydromica, with traces only of quartz and feldspar. See "Relative . . .," *Ceram. Abs.*, **20** [2] 59 (1941). K.R.

Significance of chemical findings in the pathology of mineral pneumoconioses. A. POLICARD. *Arch. Malad. Profess.*, **1** [6] 473–88 (1938).—With dust increases, calcified parts have also increased, but the silica percentages fall proportionately. In tubercular lungs there is a high dust content but a low silica content. Unfortunately, chemical findings show only total silica and not the respective totals of free silica and that occurring as silicates. Free silica is highly toxic, while the silicates are relatively innocuous. It is desirable to know the quantity of free silica, whether it exists as quartz or chalcedony. No relation has been established between the amount of fibrosis and the amount of silica present in the lungs of silicotics. The lungs of nonsilicotics may have as much or more silica than lungs freely conceded to be silicotic. The length of time the worker has spent in the dust seems to be more important than his ascertained lesions. P. emphasizes the vagueness and the mere approximation of such findings in a pathogenic study toward ascertaining the mechanisms of the pneumoconioses. Regional analyses of parts of lungs exposed to dusts have also little actual value. Chemical

analyses of different parts, anatomically distinct, of the normal human lung and the pneumoconiotic lung are inconclusive, only few data being given for either of the lungs compared. P. concludes that the proper period for chemical study of the pneumoconioses has passed. Mineralogical and histochemical studies should now be made. 14 references. K.R.

Three cases of lead poisoning with psychic disturbances. V. CHRISTIANI. *Samml. Vergiftungsfällen*, **10** [A] 53–56 (1939).—Two of these cases are typical chronic encephalopathies. The symptoms included depression, diminished ability to think, and mental slowness. There was no reaction of the pupils and no patellar reflexes, and hypesthesia existed. The other case was of the acute type; this case showed excitation, paranoid ideas, lability of emotions, difficulty in thinking, and inability to concentrate. F.S.M.

Tuberculosis case-finding in industry. C.-F. LONG. *Ind. Med.*, **9** [8] 425–27 (1940).—Five references. K.R.

BOOKS AND SEPARATE PUBLICATIONS

Active List of Permissible Explosives and Blasting Devices Approved Prior to June 30, 1940. ANON. *U. S. Bur. Mines Repts. Investigations*, No. 3533, 24 pp. Free.—The characteristics of 195 permissible explosives and blasting devices are given. R.A.H.

Index to A.S.T.M. Standards Including Tentative Standards. American Society for Testing Materials, Philadelphia, Pa., 1940. 164 pp. Free. R.A.H.

Materials Handbook. GEORGE BRADY. McGraw-Hill Book Co., New York, 1940. 4th ed. 591 pp. Price $5.00. Reviewed in *Power*, **85** [1] 59 (1941).—The revised and enlarged edition of this standard encyclopedia of complex materials of modern industry, from "abrasives" to "zirconium-ferrosilicon," gives a brief summary of the important chemical and physical properties of each subject. Such items as the composition of nonmagnetic steel, the spinning of glass fiber, and the uses of chromite refractory illustrate the wide range of information given in brief dictionary form. F.G.H.

Preliminary Survey of the Industrial Hygiene Problem in the United States. J. J. BLOOMFIELD ET AL. *U. S. Pub. Health Bull.*, No. 259, 132 pp. (1940); reviewed in *U. S. Pub. Health Repts.*, **55** [49] 2285–86 (1940).—The analysis of exposures of workers to various materials and conditions of health significance showed that slightly more than 1 million persons in this country are exposed to the inhalation of silica dust and 1½ million persons are exposed to silica dusts. In regard to the various exposures to metal dusts and fumes, the analysis indicates that approximately 800,000 persons are handling lead and its compounds, 34,000 are exposed to arsenic and its compounds, and nearly 33,000 handle mercury and its compounds. The highest exposure was in connection with agents known to produce dermatitis. A table shows that 66,417 persons are exposed to silicate dust in the clay, glass, and stone industries: 34.7% or 22,866 persons, to silicate dust (clay-workers); 26.9% or 17,686 persons, to silicate dust (glass-workers); 17.8% or 11,698 persons, to nonsiliceous dust (stone workers); and 11% or 7217 persons, to carbon monoxide. See "Industrial . . .," *Ceram. Abs.*, **18** [5] 141 (1939). K.R.

Proceedings of the Forty-Third Annual Meeting of the American Society for Testing Materials: Vol. 40. American Society for Testing Materials, Philadelphia, Pa., 1940. 1396 pp.—Committee reports and technical papers are covered. R.A.H.

Subject Index to Periodicals, 1939. Edited by J. ROWLAND POWEL. Library Assn., London, 1940. xi + 270 pp. Price 77s. Reviewed in *Nature*, **146** [3707] 630–31 (1940).—A selection of 577 English and foreign journals and transactions of societies are indexed. This current volume contains about 40,000 references to articles of scientific and technical nature. Verse and fiction are not included. Brief notes are added to titles not sufficiently indicative of the subject. See *Ceram. Abs.*, **19** [1] 36 (1940). J.L.G.

Work in the Chemical Industry. NICOLO CASTELLINO. U. Hoepli, Milan, 1940. 390 pp.—C. describes the production, use, and toxicity of approximately 24 substances, including acetone, aluminum, aniline, barium, and many others that are not important from the industrial hygiene standpoint. In the sections on poisoning, emphasis is laid on animal experiments, and investigations made in factories are also discussed. The book as a whole does not give a balanced treatment of the subject in that the length of the discussion of particular substances is often out of proportion to their importance and some important subjects are omitted. F.S.M.

PATENT

Joining ceramic objects with metal. RUDOLF SCHARFNAGEL. Ger. 681,728, Sept. 7, 1939 (July 8, 1936); VI/80*b*. 23.01; addition to Ger. 680,064 (*Ceram. Abs.*, **19** [11] 272 (1940)).—The fusing metal is an alloy of silver and cadmium; silver, copper, and cadmium; or silver, copper, iron, and cadmium. D.A.B.

CERAMIC CORPORATIONS

AND

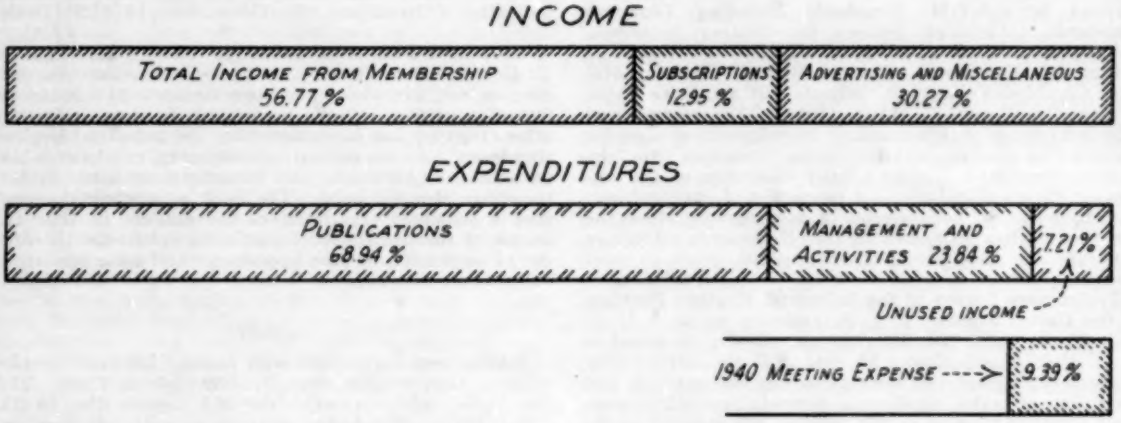
THE AMERICAN CERAMIC SOCIETY

Printing costs alone averaged in 1940 $86.70 per research report published.

The printing costs only for Ceramic Abstracts averaged $1.00 per abstract.

In addition to these printing costs there was the cost of collecting, illustrating, and editing.

The cost of the activities and management of the Society which make these research reports and abstracts available is low. Based on 1940 Total Income these figures in percentage are graphically as follows:



For forty-three years this Society has demonstrated the value of cooperation in the promotion of the ceramic arts, science, and technology, a work not duplicated by any other organization.

CERAMIC CORPORATION SUPPORT IS NEEDED

EXCERPTS FROM THE CONSTITUTION, BY-LAWS, AND RULES

Article III (1) (e) Corporation Members shall be persons, firms, or corporations who promote the objects of THE SOCIETY by the payment of annual dues as provided in the By-Laws. Such Corporation Members shall be entitled to designate a representative to be known as Voter of a Corporation Member.

Article B V (1) (e) Corporation Members shall pay a minimum annual fee of twenty-five dollars ($25.00), four dollars and fifty cents ($4.50) of which shall be a subscription to *The Journal and Ceramic Abstracts*, and one dollar and fifty cents ($1.50) of which shall be a subscription to *The Bulletin*.

Article R III (1) (e) Persons, firms, or corporations may make application for election to the grade of Corporation Member, provided it is endorsed by at least one Member of THE SOCIETY and is accompanied by the payment of dues to the first day of the next succeeding January. If the application is approved by the General Secretary, the applicant is automatically admitted to the grade of Corporation Member.

OFFICIAL PERSONNEL OF DIVISIONS, 1941–1942

	Art	Enamel	Glass	Materials and Equipment	Refractories	Structural Clay Products	White Wares
Trustee	L. E. Barringer	J. E. Hansen	G. W. Morey	H. B. DuBois	J. D. Sullivan	A. F. Greaves-Walker	F. P. Hall
Chairman	K. E. Smith	R. L. Fellows	A. K. Lyle	S. S. Cole	Gilbert Soler	J. H. Isenhour	R. Russell, Jr.
Vice-Chairman	H. S. Nash	Karl Kautz	W. C. Taylor	J. F. McMahon	R. S. Bradley	L. R. Whitaker	
2nd Vice-Chairman			C. W. Parmelee				
Secretary	Marion Fosdick	D. G. Bennett	S. R. Scholes	E. M. Rupp	C. L. Thompson	G. H. Duncombe, Jr.	F. C. Henderson
Society Nominations A..... B.....		G. N. Tuttle E. C. Aydelott	John Clyde Hostetter E. W. Tillotson	B. T. Bonnot W. R. Malkin	J. B. Austin E. H. Van Schoick	J. C. Steele, Jr. H. D. Foster	G. A. Loomis Karl Schwartzwalder
Division Nominations	Carlton Atherton A. A. Ayars	P. C. McCollom	A. N. Finn F. C. Flint W. E. Bowes	B. T. Bonnot W. R. Malkin			G. A. Loomis Karl Schwartzwalder
Papers and Program	J. P. Thorley H. S. Nash	Karl Kautz	W. C. Taylor C. W. Parmelee	J. R. Kauffman A. B. Scholes B. S. Ellefson			J. R. Beam C. J. Koenig
Membership	Harold Riegger H. H. Sanders	J. E. Roberts	John Robert Hostetter	E. P. McNamara			R. F. Sherwood
Standards	A. E. Baggs		O. G. Burch A. E. Badger F. W. Adams	G. J. Blair			F. P. Hall
Research	H. F. Bopp	F. W. C. Hutchison	N. W. Taylor J. S. Gregorius J. T. Littleton	E. W. Koenig			J. H. Koenig
Data	Marion Fosdick P. E. Cox	R. J. Whitesell	J. F. Greene F. C. Flint R. W Wampler	W. H. Vaughan			L. E. Thiess
Rules	Theodore Lenchner	G. H. Spencer-Strong	A. N. Finn	J. E. Eagle			R. M. Campbell
Councillors	C. M. Harder A. E. Baggs	J. D. Tetrick W. H. Pfeiffer	D. E. Sharp W. R. Lester	V. V. Kelsey			Harry Thiemecke R. F. Geller
Exhibitions	E. de F. Curtis		J. E. Frazier				
Industrial Management	F. H. Rhead		L. C. Roche				
Bibliography		J. E. Rosenberg					Harry Thiemecke F. P. Hall P. D. Helser

THE AMERICAN CERAMIC SOCIETY TRUSTEES AND OFFICERS FOR 1941-1942

President: J. T. Littleton, Corning Glass Works, Corning, N. Y.
Vice-President: P. D. Helser, 394 S. Lexington Ave., White Plains, N. Y.
Treasurer: C. Forrest Tefft, The Claycraft Co., Box 866, Columbus, Ohio
Secretary-Editor: R. C. Purdy, 2525 North High St., Columbus, Ohio
Past-President: J. L. Carruthers, Ohio State University, Columbus, Ohio
Past-President: A. I. Andrews, University of Illinois, Urbana, Ill.

TRUSTEES FROM INDUSTRIAL DIVISIONS*

Art: L. E. Barringer, General Electric Co., Schenectady, N. Y. (1943)
Enamel: J. E. Hansen, Ferro Enamel Corp., Cleveland, Ohio (1943)
Glass: G. W. Morey, Geophysical Laboratory, Washington, D. C. (1944)
Materials and Equipment: H. B. DuBois, Consolidated Feldspar Corp., Trenton, N. J. (1942)
Refractories: J. D. Sullivan, Battelle Memorial Inst., Columbus, Ohio (1943)
Structural Clay Products: A. F. Greaves-Walker, Univ. of North Carolina, Raleigh, N. C. (1942)
Terra Cotta: F. B. Ortman, Gladding, McBean & Co., Los Angeles, Calif. (1942)
White Wares: F. P. Hall, Onondaga Pottery Co., Syracuse, N. Y. (1944)
Institute of Ceramic Engineers: H. G. Wolfram, Porcelain Enamel & Mfg. Co., Baltimore, Md. (1944)
Ceramic Educational Council: J. W. Whittemore, Virginia Polytechnic Inst., Blacksburg, Va. (1944)

* Date of expiration of term of office in parentheses.

DIVISION OFFICERS

Art
Chairman: K. E. Smith, Newcomb College, New Orleans, La.
Secretary: Marion L. Fosdick, N. Y. State College of Ceramics, Alfred, N. Y.

Enamel
Chairman: R. L. Fellows, Chicago Vitreous Enamel Product Co., Cicero, Ill.
Secretary: D. G. Bennett, Mellon Institute, Pittsburgh, Pa.

Glass
Chairman: A. K. Lyle, Hartford-Empire Co., Hartford, Conn.
Secretary: S. R. Scholes, N. Y. State College of Ceramics, Alfred, N. Y.

Materials and Equipment
Chairman: S. S. Cole, National Lead Co., South Amboy, N. J.
Secretary: E. M. Rupp, National Engineering Co., Chicago, Ill.

Refractories
Chairman: Gilbert Solér, Timken Roller Bearing Co., Canton, Ohio
Secretary: C. L. Thompson, Harbison-Walker Refractories Co., Pittsburgh, Pa.

Structural Clay Products
Chairman: J. H. Isenhour, Isenhour Brick & Tile Co., Inc., Salisbury, N. C.
Secretary: G. H. Duncombe, Jr., 150 East Frambes Ave., Columbus, Ohio

White Wares
Chairman: Ralston Russell, Jr., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Secretary: F. C. Henderson, Hall China Co., East Liverpool, Ohio

OFFICERS OF THE FELLOWS

Dean: R. B. Sosman, U. S. Steel Corp., Kearny, N. J.
Associate Dean: T. N. McVay, University of Alabama, University, Ala.
Secretary-Treasurer: Herbert Insley, National Bureau of Standards, Washington, D. C.

INSTITUTE OF CERAMIC ENGINEERS

President: E. H. Fritz, Westinghouse Electric & Mfg. Co., Derry, Pa.
Vice-President: H. M. Kraner, Research Dept., Bethlehem Steel Co., Bethlehem, Pa.
Secretary: H. B. DuBois, Consolidated Feldspar Corp., Trenton, N. J.

CERAMIC EDUCATIONAL COUNCIL

President: C. W. Parmelee, University of Illinois, Urbana, Ill.
Secretary: R. M. King, Ohio State University, Columbus, Ohio

LOCAL SECTIONS

Baltimore-Washington
Chairman: Kenneth M. Smith, Severn Clay Co., Baltimore, Md.
Secretary: W. R. Lester, Maryland Glass Corp., Baltimore, Md.

Central Ohio
Chairman: C. J. Koenig, O.S.U. Eng. Expt. Sta., Columbus, Ohio
Secretary: M. C. Shaw, Edward Orton, Jr., Ceramic Foundation, Columbus, Ohio

Chicago
Chairman: E. E. Blankenstein, Western Electric Co., Cicero, Ill.
Secretary: C. R. Filippi, Illinois Brick Co., Chicago, Ill.

Michigan-Northwestern Ohio
Chairman: R. O. Lane, Macklin Co., Jackson, Mich.
Secretary: J. F. Quirk, A C Spark Plug Co., Flint, Mich.

Northern California
Chairman: T. K. Cleveland, Philadelphia Quartz Co., Berkeley, Calif.
Secretary: L. G. Larsen, A. J. Lynch & Co., San Francisco, Calif.

Pacific-Northwest
President: M. D. Saindon, Chehalis Brick & Tile Co., Chehalis Wash.
Secretary: C. H. Zwermann, Univ. of Washington, Seattle, Wash.

Pittsburgh
Chairman: C. L. Thompson, Harbison-Walker Refractories Co., Pittsburgh, Pa.
Secretary: L. A. Smith, Jones & Laughlin Steel Corp., Aliquippa, Pa.

Southern California
Chairman: J. G. Stewart, Braun Corp., Los Angeles, Calif.
Secretary: R. H. Martin, Vernon Potteries, Ltd., Los Angeles, Calif.

St. Louis
Chairman: H. H. Hanna, Pittsburgh Plate Glass Co., Crystal City, Mo.
Secretary: J. H. Ivery, Hydraulic Press Brick Co., St. Louis, Mo.